RADC-TDR-63-414
Final Report

DEVELOPMENT OF A MULTIPLE INSTANTANEOUS RESPONSE FILE
THE AN/GSQ-81 DOCUMENT DATA INDEXING SET

TECHNICAL DOCUMENTARY REPORT NO. RADC-TDR-63-414

October 1964

Information Processing Branch
Rome Air Development Center
Research and Technology Division
Air Force Systems Command
Griffiss Air Force Base, New York

Project No. 4594, Task No. 459402

(Prepared under Contract No. AF 30(602)-2772 by Stanford Research Institute, Menlo Park, California.)

FOREWORD

1. Personnel

A. Major Participants

C. B. Clark, Senior Research Engineer--One third time
T. J. Drewek, Engineering Associate--One half time
C. H. Heckler, Jr., Research Engineer--Two thirds time
D. P. Masher, Senior Research Engineer--One half time
V. Sanford, Engineering Associate--One half time
J. M. Yarborough, Research Engineer--Full time
E. L. Younker, Senior Research Engineer, Project Leader--Full time

B. Other Contributors

D. C. Condon, Research Engineer
D. F. Ford, Programmer
J. Goldberg, Senior Research Engineer
M. W. Green, Senior Research Engineer
W. H. Kautz, Staff Scientist
W. K. MacCurdy, Senior Research Engineer
R. C. Singleton, Senior Research Mathematical Statistician

C. Draftsman Designer

D. B. Bell

D. Technicians

R. Bennett
N. A. Dickey
N. P. Krea

2. Acknowledgments

The authors would like to acknowledge the support and encouragement of Mr. M. B. Adams and Mr. J. R. Anderson of the Computer Techniques Laboratory and of Mr. R. Ferris and Mr. S. Stromick of the Rome Air Development Center. The many contributions of other members of the laboratory are also gratefully acknowledged.

3. Authors of the Final Technical Report

E. L. Younker
D. C. Condon
C. H. Heckler, Jr.
D. P. Masher
J. M. Yarborough

AIR FORCE, GAFB, N.Y., 6 Nov 64-100

Key Words: Computer - Storage and Retrieval

ABSTRACT

An experimental model of an electronic reference retrieval file in which all file entries are interrogated simultaneously has been designed and constructed. The principal purpose of this work is to demonstrate the usefulness of a rapid-feedback, man-machine relationship in a data retrieval system.

The experimental model (designated the AN/GSQ-81 Document Data Indexing Set) is designed to store the indexes to 5,000 documents. Each document is given an accession number and is described by up to eight English words (descriptors) selected from a 3,000 word dictionary. The delivered model contains a 1,000 word dictionary and the indexes to 1,100 documents. A search question, consisting of one to eight descriptors in their natural English form, is entered by means of an electric typewriter. The machine indicates immediately whether or not any file item satisfies the search question, and if so, how many file items respond. The machine then resolves multiple responses and types out the accession number and full set of descriptors of each responding document.

The document indexes and the words of the dictionary are stored in wiring patterns associated with arrays of linear ferrite magnetic cores. During entry of the search question, the dictionary magnetic store is interrogated by the alphabetic code of each search word. If the word is not contained in the dictionary, it is automatically rejected. After all words of the search question have been entered, the document magnetic store is interrogated by the search question in superimposed code form. Response to a word validity test or to the file search is obtained in less than six microseconds.

This equipment can handle synonymous input descriptors and has the capability for automatically modifying the manually inserted search question according to certain logical rules. New searches based on the modified search question (for example, substitution of a see-also reference for one of the original descriptors) are initiated automatically.

PUBLICATION REVIEW

This report has been reviewed and is approved. For further technical information on this project, contact Mr. Stephen Stromick, EMIIH, Ext. 71105.

Approved: STEPHEN STROMICK
Project Engineer
Directorate of Intelligence & Electronic Warfare

Approved: FRANK J. TOMAINI
Chief, Information Processing Laboratory
Directorate of Intelligence & Electronic Warfare

FOR THE COMMANDER: IRVING J. GABELMAN
Director of Advanced Studies

TABLE OF CONTENTS

1. Introduction 1

A. Dates of Development Program 1

B. Background 1

C. Original Specifications of Experimental Model 2

D. Changes in Specifications 5

E. Note on Material Presented in Report 7

2. Summary 8

3. The Experimental Model 10

A. General Description 10

B. System Design 16

C. Circuit Design 31

D. Magnetic Design 51

E. Mechanical Design 62

F. Experimental Results 65

4. Conclusions and Recommendations 80

LIST OF APPENDIXES

APPENDIX I	OPERATION OF THE AN/GSQ-81 DOCUMENT DATA INDEXING SET
APPENDIX II	LOGICAL DESIGN OF THE SYSTEM
APPENDIX III	REDUCTION OF RAW DOCUMENT DATA TO THE FORM USED IN THE WIRING AID
APPENDIX IV	PREPARATION OF THE WIRED ITEM TRAYS
APPENDIX V	ALTERNATE METHODS OF PREPARING WIRED-IN INFORMATION

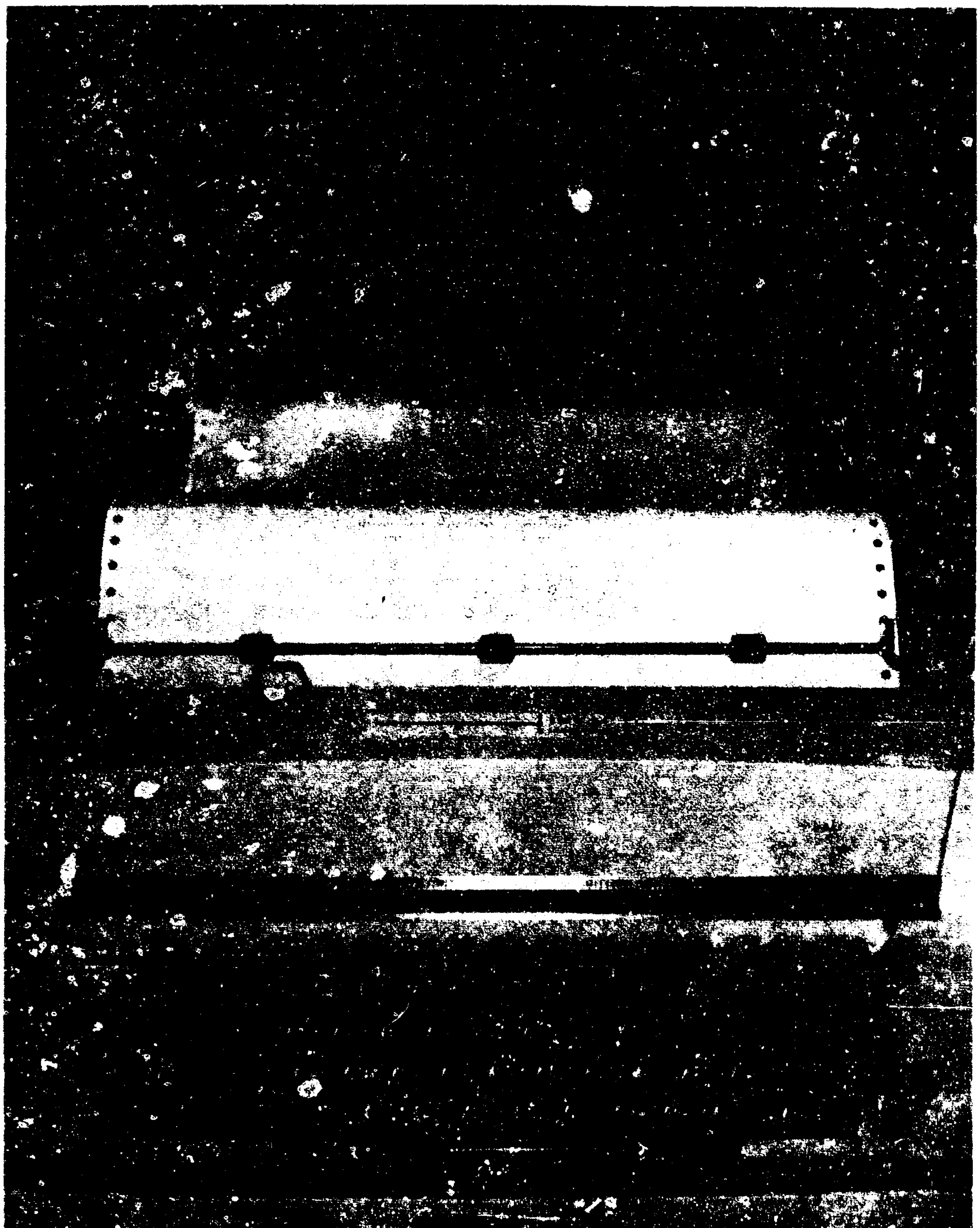
LIST OF ILLUSTRATIONS

Fig. 1	Simplified Block Diagram of MIRF Experimental Model (Document Data Indexing Set AN/GSQ-81)	12
Fig. 2	Front View of Document Data Indexing Set	14
Fig. 3	Close-up of Control Area	15
Fig. 4	Rear View of Equipment Cabinet (doors removed)	17
Fig. 5	Logic and Control Section	18
Fig. 6	Front View of MIRF Section	19
Fig. 7	Core-wiring Arrangement for MIRF Memory	21
Fig. 8	Circuit for Testing Inclusion	23
Fig. 9	Circuit for Testing Identity	24
Fig. 10	Logical Structure of MIRF Experimental Model (Revised) . .	26
Fig. 11A	Typical DTL Circuit	33
11B	RTL Circuit designed for the MIRF System	33
Fig. 12	Basic Centralab Unit and Circuit for Basic NAND Gate . . .	36
Fig. 13	Component Assembly of Gate Logic Board	38
Fig. 14	Component Assembly of Flip-flop Logic Board	39
Fig. 15	Component Assembly of Shift Register Logic Board	40
Fig. 16	Component Assembly of One Shot Logic Board	41
Fig. 17	Component Assembly of Emitter Follower Logic Board	43
Fig. 18	Component Assembly of MIRF Clock System Board	44
Fig. 19	Component Assembly of MIRF Driver Board	45
Fig. 20	Component Assembly of Split Switch Driver Board	48
Fig. 21	Component Assembly of Source and Drain Logic Board	49
Fig. 22	Simplified Example of Inter-item Capacitance	57
Fig. 23	Worst-case Model for MIRF Analysis	57
Fig. 24	Detail of Primary Winding	57

Fig. 25	Magnetic Potentials in Core, shown as if core were spread out in one dimension	61
Fig. 26	Detail of Leakage Flux Cancellation Scheme	61
Fig. 27	Explided View of MIRF Module	64
Fig. 28	Bottom View of Core Bobbin Assembly (partially wired)	66
Fig. 29	Completely Wired Dictionary Item Tray	67
Fig. 30	Close-up of MIRF Module in Equipment Cabinet of Experimental Model	68
Fig. 31	Format of Typewritten Record of a Search	70
Fig. 32	Example of Reducing the Number of Responses by Increasing Specificity of Search Question	72
Fig. 33	Examples of Synonym Substitution	73
Fig. 34	Examples of "See Also" Special Search	75
Fig. 35	Example of "See Also" and "Asterisk" Special Searches	76
Fig. 36	Example of Response to a Single Word Search Question	79
Fig. III-1	Format for Coding MIRF Document Information	III-2
Fig. IV-1	Over-all View of Item Tray Wiring Aid	IV-2
Fig. IV-2	Close-up of Partially Wired Item Tray and Wiring Jig	IV-4
Fig. V-1	Etched-Copper Mylar Item Sheet	V-3

LIST OF TABLES

Table III-A	Format for Dictionary Data Punched Cards	III-7
Table III-B	Format for Document Data Punched Cards	III-7
Table III-C	Format of Record for Dictionary MIRF Wiring Punched Card	III-9
Table III-D	Format of Record for Document MIRF Wiring Punched Card	III-13
Table III-E	Alphabetic Code for Descriptor	III-10
Table III-F	Accession Number Decimal Digit Code	III-11
Table III-G	Primary Word Serial Number Bit Code	III-11
Table III-H	Synonym Word Serial Number Bit Code	III-11



Frontispiece

1. Introduction

A. Dates of Development Program

All work related to the design, construction, and checkout of the experimental model of the Multiple Instantaneous Response File described in this report was carried out during the period from 23 May 1962 to 23 July 1963.

B. Background

During the period from 1 January 1960 to 31 July 1961 a study* was made of the feasibility of constructing a data retrieval file of very large capacity in which all the data are interrogated simultaneously. One characteristic of the file was that it should be very large, containing the order of a million items of information. An item of information should consist of a single record, including an identification number, an abstract and appropriate logical specifications. Another important characteristic was that during a search, the entire file should be tested instantaneously (this requirement precluded the use of a serial search). The response time for all items responding to the search question should approach zero. The response should consist of the item identification number and index data in the form of an abstract.

During the study, general concepts for solving the search problem were developed. Codes and searching techniques suitable for such a file were examined and a simple and efficient testing algorithm for distinguishing between simultaneously responding items (multiple responses) was originated. Also several physical realizations suitable for such an index file were investigated. It was concluded from the study that the development of a data retrieval file having the stated specifications was feasible and that a magnetic implementation of the file with permanent storage of file information was attractive.

---

*This study was sponsored by Rome Air Development Center under Contract AF30(602)-2142. Refer to report RADC-TR-61-233, "Multiple Instantaneous Response File," by J. Goldberg et al, August 1961. ASTIA Report # AD 266 169.

During the final quarter of the study contract the preliminary design of an experimental model to demonstrate the essential features of a Multiple Instantaneous Response File was worked out. It was concluded that a model containing the order of 20,000 file items would be large enough to provide significant results and could be developed for a reasonable cost. These conclusions formed the basis for the specifications of the experimental model developed under the present contract.

C. Original Specifications of the Experimental Model

The experimental model described in the original proposal for research and the resulting contract has the following specifications:

(1) The size of the MIRF file shall be 1,000 items with design provisions for expansion to 5,000 items.

(2) Each item in the MIRF file shall be indexed by not more than 8 descriptors. A descriptor is an English word having 10 or fewer letters.

(3) Encoding of the items shall be accomplished by utilizing superimposed coding.

(4) The design of the superimposed code shall be adequate to represent a maximum of 3,000 descriptors.

(5) At least two descriptors shall be used in an interrogation.

(6) A dictionary file capable of holding 3,000 descriptors shall be provided as a part of the experimental model. Entries in the dictionary shall be one of the following types:

(a) Primary descriptor. A primary descriptor is one that can be used in indexing an item in the file. It can be used in composing the search quiz and can appear in the printed output of items that respond to a search.

(b) Synonym. A synonym is a descriptor whose meaning is synonymous with one of the primary descriptors. It can be used in composing the search quiz, but is not used to

describe an item stored in the file and cannot appear in the printed output.

(c) Variations on primary descriptor.

(i) A special character, such as an asterisk, may be associated with a primary descriptor.

(ii) A "see-also" reference to another primary descriptor may be associated with a primary descriptor.

(iii) Both a special character and a "see-also" reference may be associated with a primary descriptor.

(7) The dictionary store shall use the same techniques as the MIRF file and shall include circuits for:

(a) Translating search criteria in English into the code form required for the internal search of the file.

(b) Translating the descriptor serial number arrived at during a search of the file into its English counterpart.

(c) Recognizing asterisk or "see-also" reference symbols associated with descriptors.

(d) Matching corresponding primary descriptors and synonyms and corresponding descriptors and "see-also" references.

(8) In response to an interrogation, the machine shall provide the following information:

(a) A YES or NO answer as to whether any stored item matches the interrogation criteria.

(b) An approximate numerical count of the number of YES responses.

(c) The descriptors of all items associated with the YES responses. The descriptors of several simultaneously responding items may appear in time sequence.

(d) The accession numbers of all the items associated with the YES responses.

NOTE: The YES/NO response and the number of Yes responses shall be displayed visually. The accession number and the list of descriptors of the first, and each subsequent YES response shall be printed out on the same typewriter that is used for quiz entry. The format of the printed output information shall be determined jointly by RADC and SRI.

(9) In addition to the capability of resolving multiple responses to a search quiz, the model shall be capable of demonstrating the following logical operations:

(a) Handling of synonyms. When a synonym is used in composing the search quiz, the machine shall automatically substitute the appropriate primary descriptor for the synonym and carry out the search on the primary descriptor.

(b) Modification of search quiz by "see-also" reference. When a descriptor having an associated "see-also" reference is used in composing the search quiz, the machine shall automatically initiate a new search (after the one on the original search quiz has been completed) in which one of the original descriptors has been replaced by its "see-also" reference. For purposes of demonstration, it shall be considered adequate to perform only one additional search and to choose arbitrarily the first input descriptor having a "see-also" reference as the one to be replaced in forming the new search quiz. To aid in separating the printout of the first search from the printout of the automatically initiated search, the "see-also" reference descriptor shall be printed as a heading for the second printout.

(c) Generation of new search quiz. The machine shall generate a new search quiz in which new search descriptors are selected from the descriptors of items that respond to the original search. For purposes of demonstration, it shall be considered adequate to generate a new search cycle by selecting descriptors with asterisks from items that match the original search quiz. In particular, the "asterisk" search quiz shall be formed by retaining the first descriptor that is typed into the MIRF during composition of the original quiz and combining with it one asterisked descriptor (different from all the original descriptors) from an item that responds to the original quiz. An asterisk search cycle shall consist of no more than two automatically initiated searches (for example, a search based on a quiz formed by combining the retained descriptor with an asterisked descriptor from the first responding item, and one based on the combination of the retained descriptor with an asterisked descriptor from the second responding item). To aid in separating print outs of successive searches, the two descriptors used in an asterisk search shall be printed as a heading for the asterisk search printout.

D. Changes in Specifications

During the first quarter several changes in the original specifications were made.

(1) Use of asterisk on descriptors. During the selection (at RADC) of documents for the MIRF file, it was found desirable to attach the asterisk symbol to a descriptive word based on its use in a particular document, rather than to make a fixed assignment of an asterisk to a word. It was agreed* to make this change in the use of the asterisk.

*Letter to Mr. Ronald Ferris from Mr. E. L. Younker, dated 13 August 1962.

(2) Phrase descriptors. In selecting documents (at RADC) for the MIRF file, it was found very desirable to allow the use of phrases of two or more words in describing a document. However, in order to prevent additional costs, it was required that no significant change be made in the model to accommodate phrases. To meet these conflicting demands, it was agreed** that phrases would be used in a limited way.

(a) Characteristics of Descriptors

(i) Definition of Descriptor. The descriptors used in the MIRF model shall be composed of English words containing ten or fewer alphabetic characters. The use of two or more words to form a conceptual entity (descriptor) shall be permitted. Thus, a descriptor may be either a single word or a "phrase" of several words.

(ii) Restrictions on Descriptors. Only single word descriptors shall be in the special operations: synonym substitution and the automatically initiated searches. Phrase descriptors must not be associated in any way with a synonym, see also, or asterisk expression.

(b) Operation of Experimental Model with Respect to Descriptors

(i) Descriptor Input. The model shall have the capability of accepting either a single word or phrase descriptor. The human operator will be required to type a comma after each input descriptor in the search question except the last descriptor. In this case he will be permitted to type a period. Whenever a phrase descriptor is typed in, the operator will enter a space between the words of the phrase.

**Letter to Mr. Ronald Ferris from Mr. E. L. Younker, dated 13 July 1962.

(ii) Print-out of Descriptors. The model shall have the capability of distinguishing between single word and phrase descriptors for purposes of print-out. The descriptors of a responding document shall be separated by commas in the print-out format, and the words of a phrase shall be separated by spaces.

(iii) Searching an Input Question. The search that results from an input question shall be based on the words (not descriptors) used in the search question. So far as searching is concerned, the model will not be capable of distinguishing between single word and phrase descriptors. Because of this a simple change in the specification of the asterisk search is necessary. Instead of retaining the first descriptor (as defined above), the first word should be retained. Instead of comparing the asterisked descriptor from the responding document with the input descriptors, compare it with the input words.

(c) Effect on Capacity of Dictionary. Because the definition of a descriptor has been changed to include phrases, the capacity of the dictionary file will be less than 3,000 descriptors. However, the capacity of the dictionary in terms of words will not change. The dictionary will still have the capacity for 3,000 words, and these words may be used to form descriptors as desired.

E. Note on the Material Presented in this Report.

In the body of this report emphasis is placed on a description of the experimental model of the Multiple Instantaneous Response File. Information on related work performed under this contract, such as processing the raw data for 1100 documents that were supplied by RADC, is contained in a set of appendixes.

2. Summary

The development of an experimental model of a Multiple Instantaneous Response File has been completed successfully. The experimental equipment contains more than 1,000 document indexes in its document file. The descriptors used in the document indexes are chosen from a dictionary of 1,000 words that is also part of the equipment. The logical, circuit, and mechanical designs of the model provide for a simple expansion to 5,000 document indexes and to a 3,000 word dictionary. Experience with the equipment during the checkout phase indicates that expansion to the design figures could be accomplished with little difficulty.

The specifications on a manually initiated search (listed in detail above) are satisfied by the experimental equipment. Excellent communication between a human operator and the machine has been experienced. The operator is required only to enter a search question as a group of English words by typing them on a conventional typewriter and to observe the results of the search typed out in simple format on the same typewriter. Translation of the English words into machine coding during the input phase and from coded machine responses into English words during the output phase are performed automatically. The requirements for modification of the manually inserted search question and the automatic initiation of new searches have also been satisfied. Experience with the machine shows that the see-also substitution is an important feature. Usually the additional see-also special search obtains pertinent additional responses relative to the original search and in some cases pertinent responses are obtained from the see-also search when there are no responses to the original search.

The experimental Multiple Instantaneous Response File is an all-solid state equipment. Transistor drive circuits capable of supplying two amperes of current to magnet circuits, special discriminating amplifiers capable of operating reliably with a poor signal-to-noise ratio input signal, and transistor logic circuits tailored to the requirements of the system (high reliability, low cost, and moderate speed) were designed and constructed. About 300 current drive

transistors, 2500 logic transistors, 2500 printed gate circuits (a group of 6 resistors, 2 capacitors and their interconnecting wiring on a passive substrate) and 5000 diodes are used in the system.

The documents that are stored in the experimental model were selected by the sponsor from ASTIA Technical Abstract Bulletins (TABs). The information concerning the selected documents was supplied by the sponsor in the form of a marked TAB abstract. Considerable effort was expended in reducing the raw data to a form that could be stored in the memory of the equipment. First, the relevant data from the TAB abstracts were reproduced in punched card form. Then computer programs were written for taking this raw data and preparing the data for each document to be stored in the machine (coded information for the accession number, the descriptors, and the search logic). The computing was carried out on the Control Data Corporation model 160-A. The resulting set of punched cards was used in special wiring arrangement that prepared the information that was stored in the machine. One punched card containing all the detailed information for one document was inserted into a punched card reader whose outputs were connected to a wiring jig. For each document a unique set of lights in the wiring jig was turned on and a wiring path was established. Be means of the computer handling of the raw data and the special attention given to the wiring arrangement, the errors in wiring the document information were reduced to the order of 1 error in more than 7,000 operations.

3. The Experimental Model

A. General Description

(1) Functions of the Document Data Indexing Set

The AN/GSQ-31 Document Data Indexing Set is basically a file of document indexes and a means of retrieving particular document indexes of interest. This model contains the indexes of approximately 1000 documents that have been selected from the ASTIA Technical Abstract Bulletin. Each document is indexed by an accession number and a group of key words that describe the contents of the document. The vocabulary required to describe the 1000 stored documents contains about 1000 words. For the purpose of translating between the English formof these words and the coded form used inside the machine, a dictionary of 1000 words is contained in the equipment. The basic design of the data indexing set provides for expansion of 5000 document indexes and a 3000 word vocabulary.

The basic function of the document data indexing set is to permit the retrieval of document indexes that are related to particular subjects of interest. It allows an operator to ask a question about what is contained in the file in the form of a group of English words by typing these words on an ordinary typewriter. The machine compares the word used in the search question with the words that are used to describe the documents that are contained in the file. The comparison between the search words and the documents is made for all documents simultaneously. The machine instantaneously determines if any documents in the file include the search question. If there are none, the machine indicates visually that there is no response. If there is at least one, the machine counts the number of responding documents and indicates visually this number. Then it types out the indexes of all responding documents on the same typewriter that was used to ask the question. There is essentially no delay between the signal that starts the search and the beginning of typing out the responding documents. Because the results are immediately available, and because they have enough useful information to give a good idea of what each document is about, this

document data indexing set makes it feasible to start the document search with a general question and to use the information received to define a more specific question. In this way it is possible to "home in" quickly on the documents of special interest.

This equipment has the capability for automatically modifying the search question inserted by the human operator and initiating a new search. In one type of machine initiated search, the original search question is modified by information associated with the input question. If any of the input words have attached to them a "see also" reference, that "see also" reference will be substituted for the original word to form the new search question. A second kind of machine initiated search uses information obtained from responding documents to modify the original search question. In this case, words appearing in responding documents that are marked by an asterisk are stored in the machine memory and later are used to replace a word in the original search question.

(2) Logical Organization of the Document Data Indexing Set

The logical organization of the Document Data Indexing Set is illustrated by Fig. 1. Information pertaining to the document indexes and to the key words used in the document indexes is contained in major units called MIRF. A MIRF is basically a magnetic memory in which information is permanently stored in the wiring associated with the magnetic cores. The Document MIRF is the principal element of the system. It contains for each stored document index the document accession number and the key words (in coded form) that describe that document as well as a search code field that is used in the searching process. The Dictionary MIRF translates during the input phase of operation from the alphabetic code of the English word descriptor that is entered from the typewriter to the binary serial number assigned to that English word for use inside the machine. During the output phase of operation, the Dictionary MIRF translates from the binary serial number of a word that is obtained during a search to the

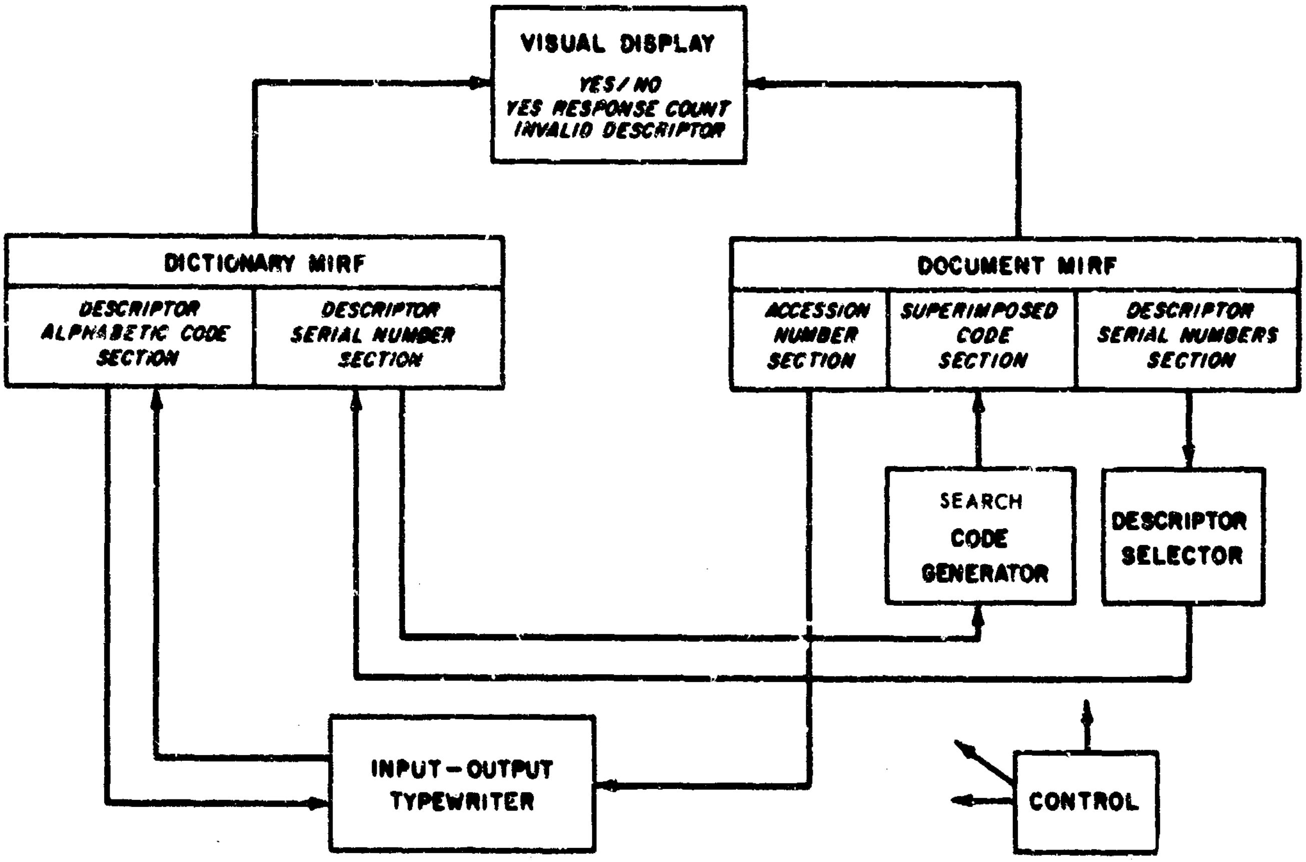


Figure 1. Simplified Block Diagram of MIRF Experimental Model

8-4110-1

alphabetically coded form of that word.

After the binary serial number of an input English word has been generated, this binary number is translated by a logical process in the Search Code Generator into a search code that is assigned to the particular English word. The search codes of successive words of a search question are superimposed by adding them together logically. When the search question is complete, the superimposed search code of the question is compared with the superimposed code section of the Document MIRF. Each document index whose search field includes the superimposed code of the search question is said to respond to the question. By a process that is described later,the accession number of a particular responding document is generated. Then the binary serial numbers of the English words contained in the document index are generated one at a time. By means of the Descriptor Selector each serial number is transmitted to the dictionary MIRF, where it is translated to the alphabetic code of the English word.

(3) Equipment

The AN/GSQ-81 Document Data Indexing Set is a solid state machine. Storage of document index information is provided by arrays of linear ferrite cores in the MIRF units. Drive currents to the magnetic cores are furnished by transistor switches and the output voltages from the core arrays are amplified by transistor amplifiers. All logical processes and control of operations in the MIRF units are performed by transistor logic circuits. Solid state power supplies are also used.

A front view of the document data indexing set is shown in Fig. 2 The main equipment cabinet, the input-output typewriter, the auxilliary typewriter cabinet and the display and control unit can be seen in this photograph. Figure 3 shows a closeup view of the control area. The input-output equipment, the INVAC Model TMP200, consists of the typewriter and the equipment cabinet seen at the left of the table. An IBM Selectric Typewriter is used in this equipment.

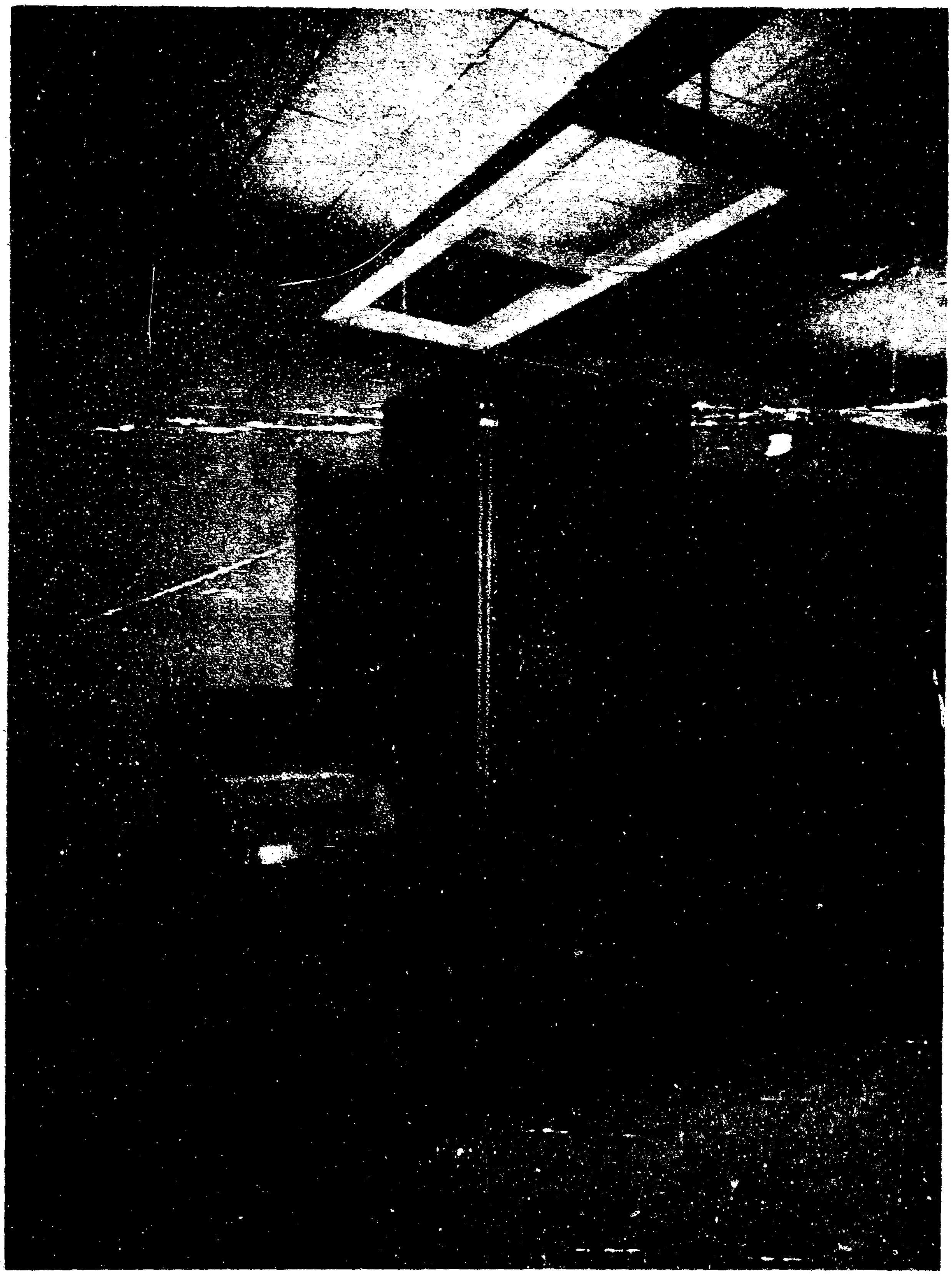


Figure 2. Front View of Document Data Indexing Set

Figure 3. Close-up of Control Area

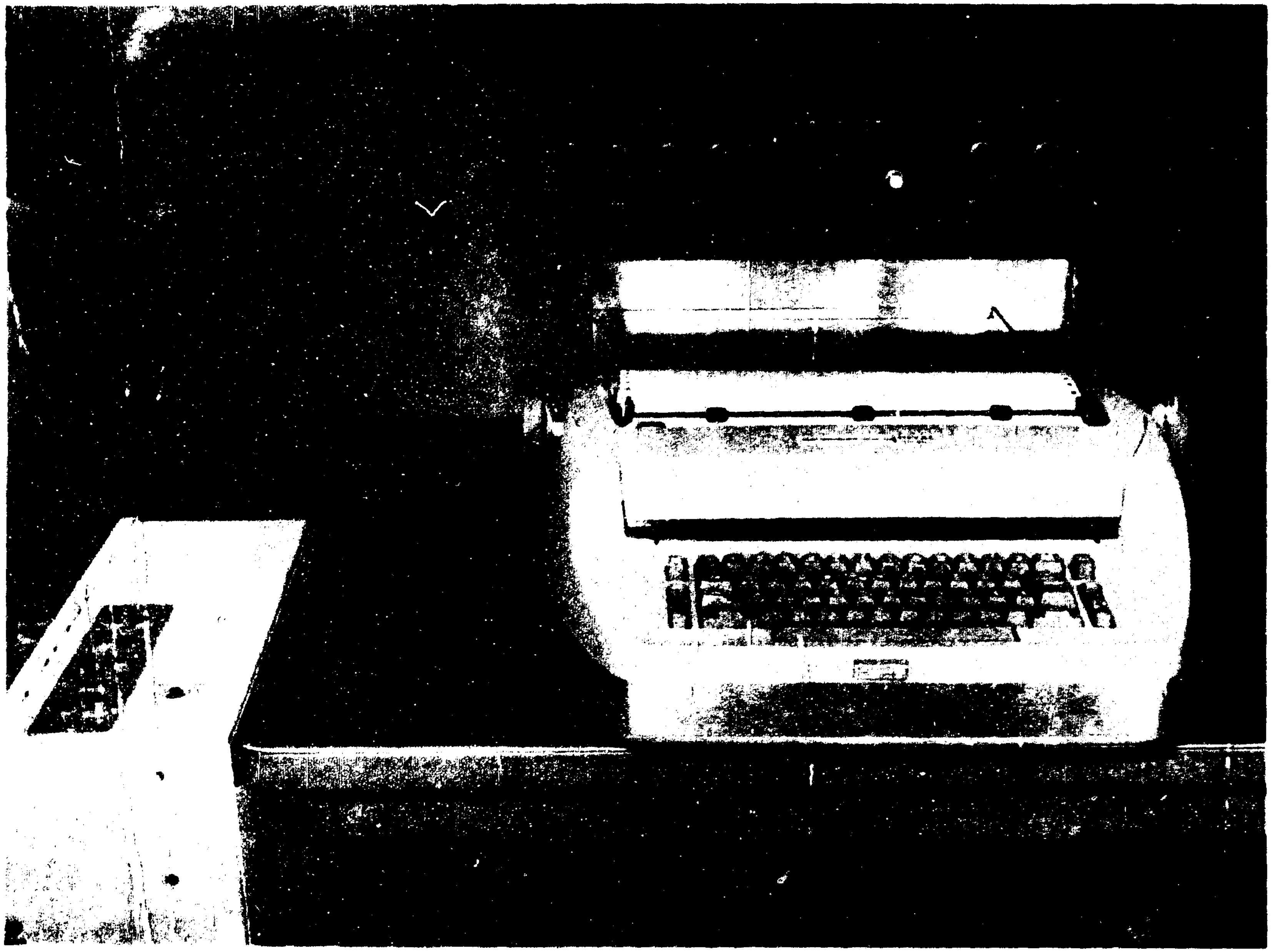


Figure 3. Close-up of Control Area

Behind and above the typewriter can be seen the operator's display and control panel. Fanfold paper that is to be fed into the typewriter is stored in the bottom of the cabinet on which the display and control panel is mounted.

Figure 4 shows a rear view of the equipment cabinet with the doors removed. The righthand portion of the cabinet contains logic circuits for control of the system, arranged in modules of plug-in transistor logic boards. The dictionary MIRF unit is contained in the center portion of the cabinet. Directly beneath the MIRF unit are two modules of drive circuits which provide current to the MIRF. In the left portion of the cabinet are the document MIRF and the transistor circuits for providing drive currents to it. It will be observed that space has been allowed for one additional MIRF unit in the center section and for two additional MIRF units in the lefthand section. This is to provide for the expansion of the dictionary to 3,000 words and expansion of the document index MIRF to 5,000 document indexes.

A closer view of the logic and control section is shown in Fig. 5. Here the inside door on which the transistor circuits are mounted has been opened to show the wired side of the transistor modules. All connections to the connector pins have been made by the wire wrap method. Additional modules of transistor circuits used in the over-all control can be seen inside the cabinet; these are mounted on an auxilliary door that opens from the front of the equipment cabinet.

A front view of the cabinets that house the MIRF units and their drivers is shown in Fig. 6. Here the document MIRF unit has been pulled out to show it in its extended position. Below the MIRF units the wiring side of the transistor drive modules can be seen.

B. System Design

(1) Magnetic Implementation of the MIRF Unit

The MIRF units of the document data indexing set are built according

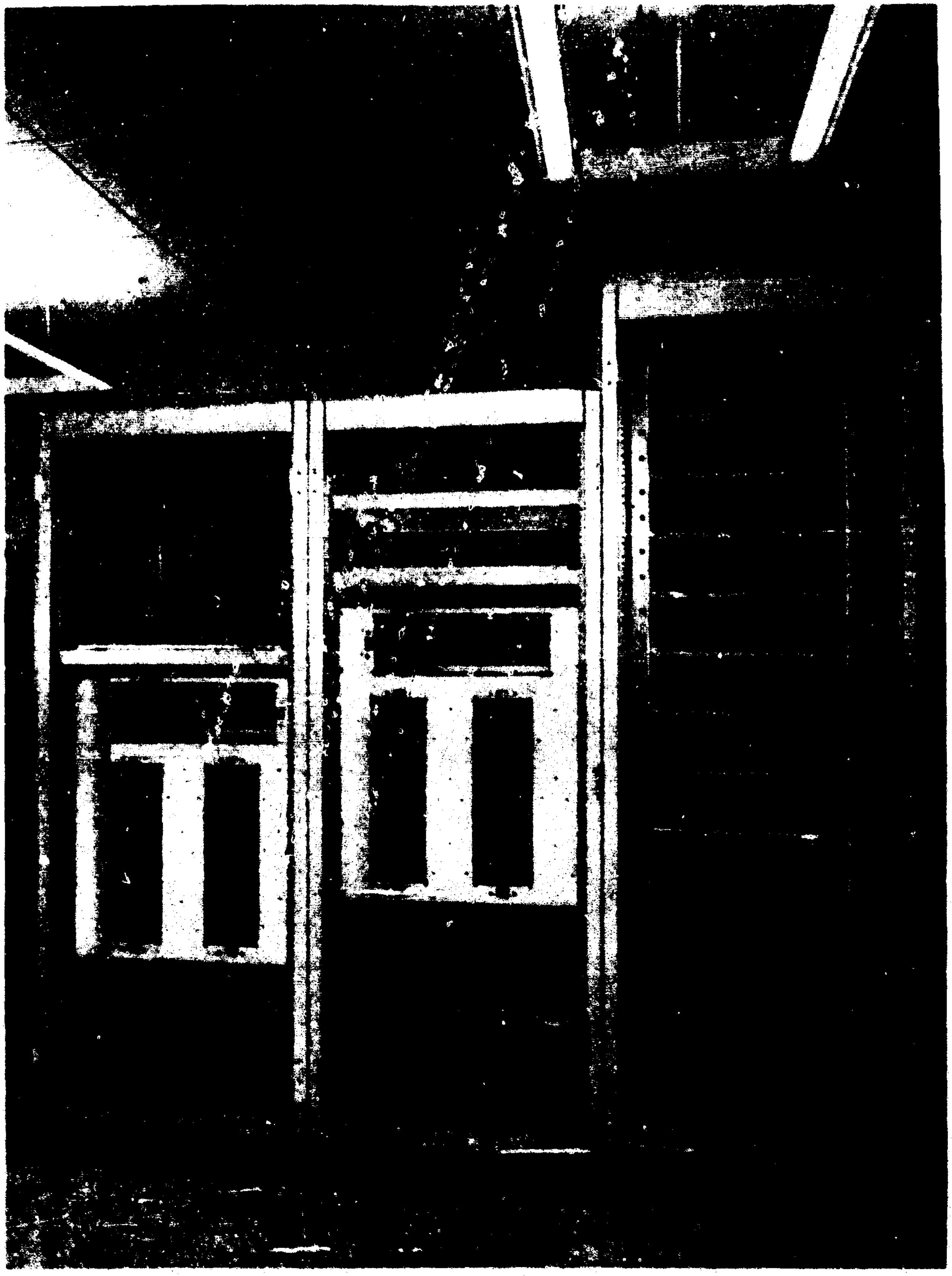


Figure 4. Rear View of Equipment Cabinet (doors removed)

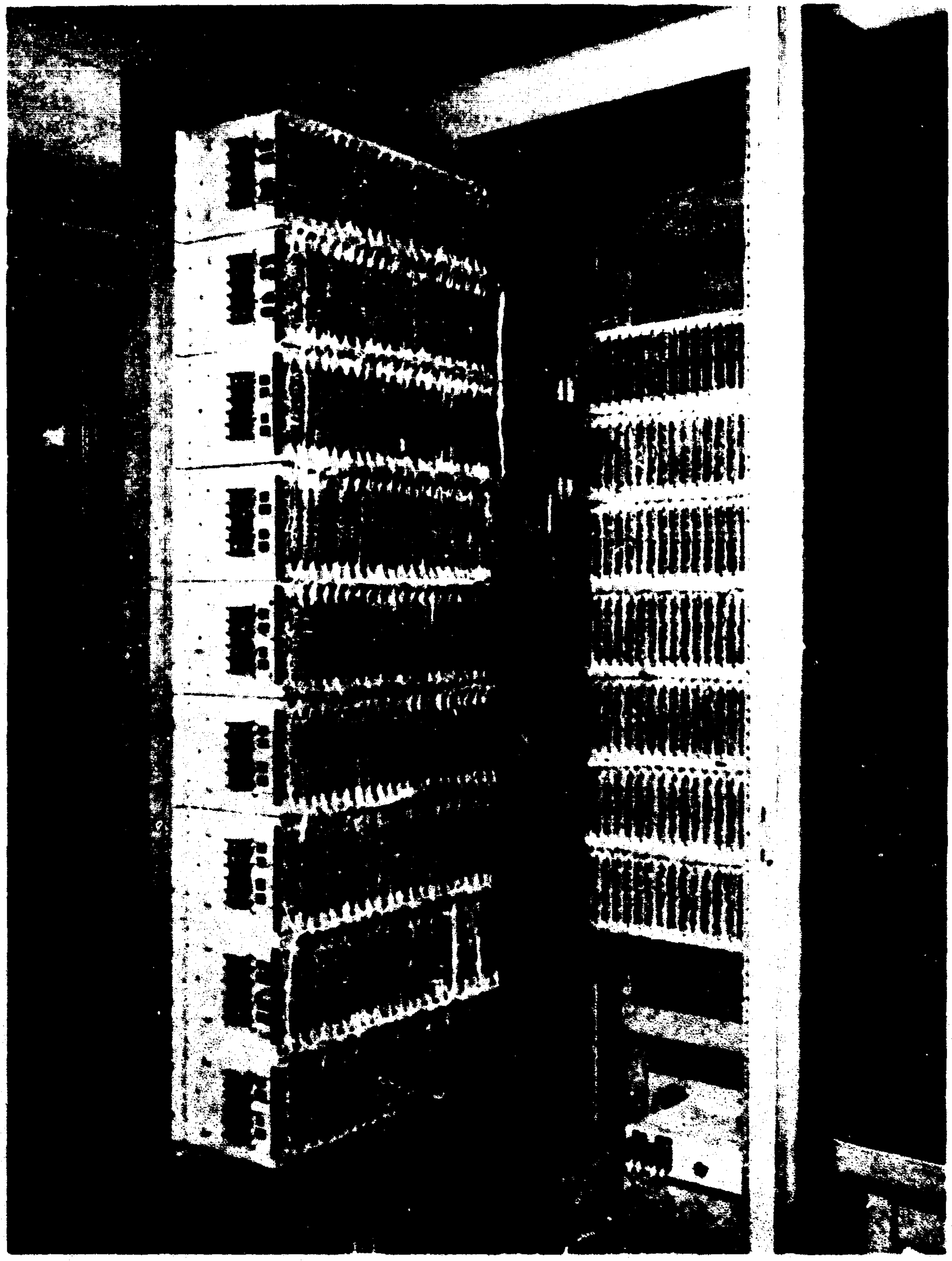


Figure 5. Logic and Control Section

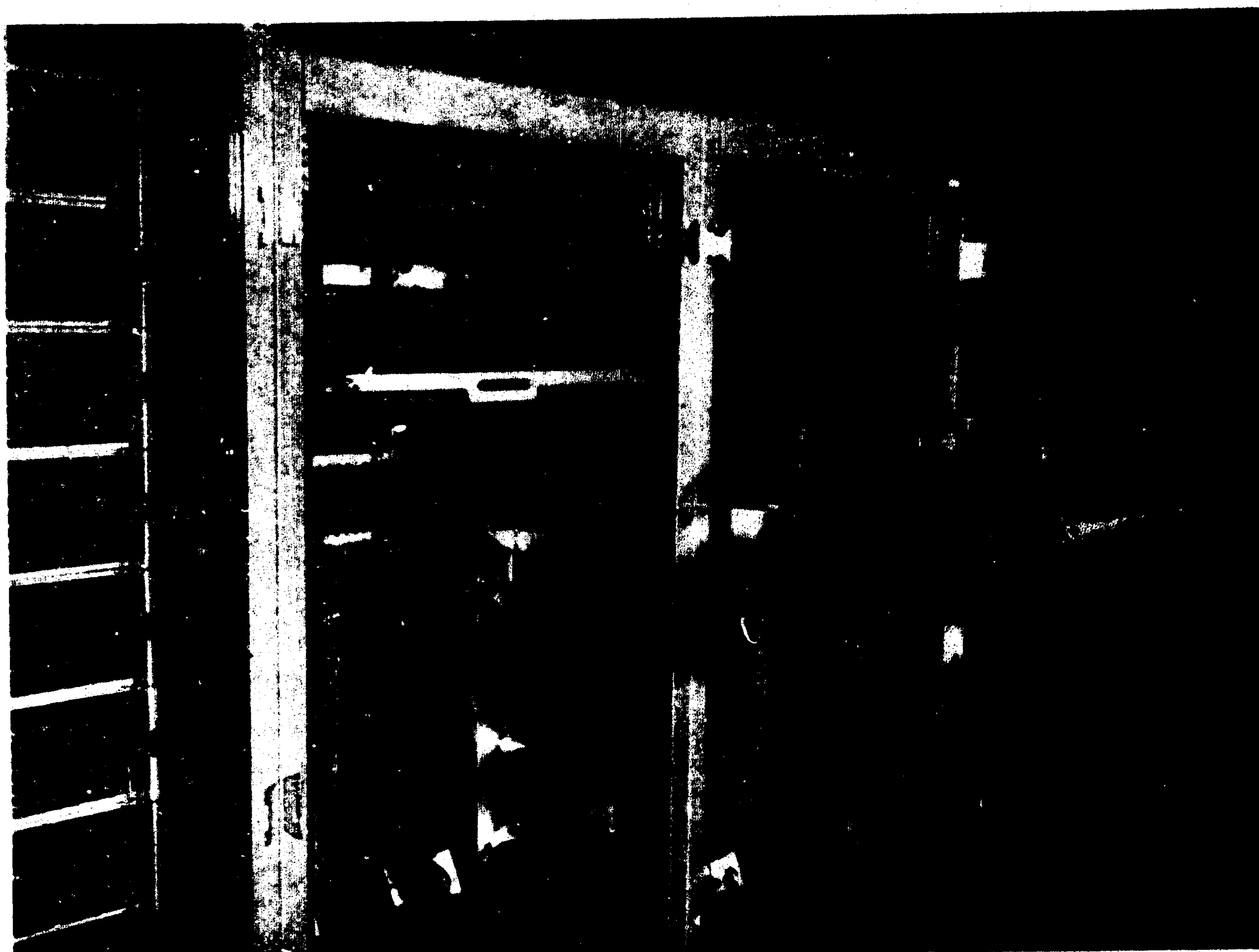


Figure 6. Front View of MIRF Section

to an idea that was generated during the earlier study contract*. This scheme, called the diode-Dimond ring realization for MIRF, has the properties of an associative memory. Information is stored in unique wiring patterns associated with an array of linear ferrite cores as illustrated by Fig. 7. Each item of stored information (a document index in the document MIRF or a descriptor in the dictionary MIRF) is represented by a conductor that passes through or around each associated core in a unique pattern determined by the information it contains. In series with each conductor is a diode. The cathodes of many diodes are connected together to form the input to a detector amplifier. Notice that one core is required for each bit of information but that each core can be associated with a particular bit of many item conductors.

Each core has an input winding that can be selected by means of a switch. All cores whose selector switch is closed will be energized when a drive pulse is applied. A voltage will be induced in each item conductor that threads an energized core, but no voltage will be induced in conductors that do not thread the core. A test can be made on the information stored in many cores by selecting a particular set of cores and energizing them. In order for an item to match the test information, its conductor must pass outside of every energized core. Then no voltage will be generated in the item wire and the input to the detector amplifier will be held near ground through the item diode. Voltages will be induced in the conductors of items that do not match the test; the polarity of these voltages is chosen to back-bias the associated diodes. If no item matches the test information, a voltage will be induced in every item conductor and every diode will be back-biased. The input to the detector will then assume a significantly negative voltage. Thus the presence or absence of desired stored information can be determined by applying the drive currents to a particular set of cores. This is a function of an associative or content addressed memory to

*See final report, RADC-TR-61-233, prepared under Contract AF 30(602)-2142, "Multiple Instantaneous Response File," by J. Goldberg and others, dated Aug. 1961, pp. 167-186

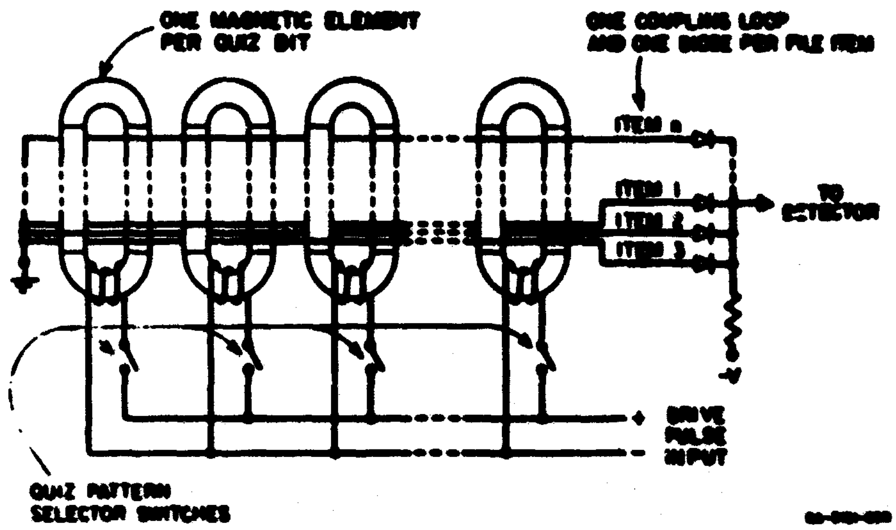


Figure 7. Core-Wiring Arrangement for MIRF Memory

indicate the presence or absence of certain information based on the detailed contents of a search question without regard to the actual location (or address) of that information.

Now consider in more detail how a bit of information of a search question is compared with information in a MIRF unit. Figure 8 illustrates how a test to determine whether or not the test bit is included in the stored information is made. This circuit is typical of those used in the superimposed section of the document MIRF. One core is used to store the k^{th} bit of many items. The k^{th} bit of the search question is stored in a flip-flop whose ONE side is connected by way of an AND gate to a drive amplifier which in turn is connected to the primary winding of the k^{th} core. The conductor of an item whose k^{th} bit is equal to ONE (conductor #1) passes outside the k^{th} core. On the other hand, the conductor of an item whose k^{th} bit is equal to ZERO (conductor #2) threads the core. If the flip-flop stores a ONE, the primary winding of the core will be energized when the timing pulse is applied to the AND gate. A voltage will be induced in conductor #2 (indicating a mismatch) but none will be induced in conductor #1 (indicating a match). If the flip-flop stores a ZERO, the primary winding will not be energized because the timing pulse will be blocked at the AND gate. So no voltage will be induced in either conductor and a match will be indicated on both lines. Therefore it can be seen that a stored ONE bit includes both a test ONE and a test ZERO, while a stored ZERO bit includes only a test ZERO.

The circuit for testing for identity between the test bit and the information stored in the MIRF is shown in Fig. 9. This circuit is typical of those used in the alphabetic descriptor portion of the dictionary MIRF. The j^{th} bit of many items is stored in a pair of cores j_A and j_B. The j^{th} bit of the test question is stored in a flip-flop. In this case both the ONE and ZERO sides of the flip-flop are connected to AND gates whose outputs control drive amplifiers that are connected to the primary windings of cores j_A and j_B. The

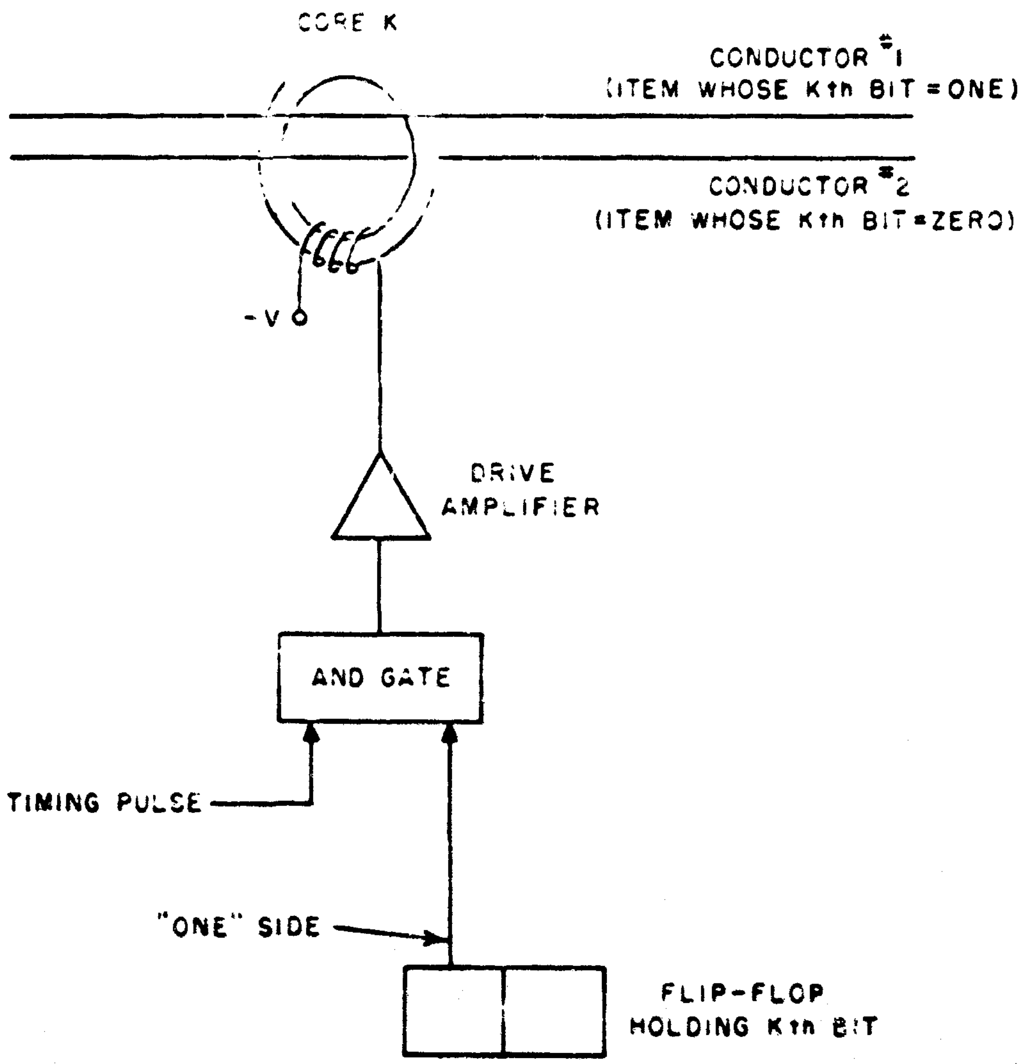


Figure 8. Circuit for Testing Inclusion

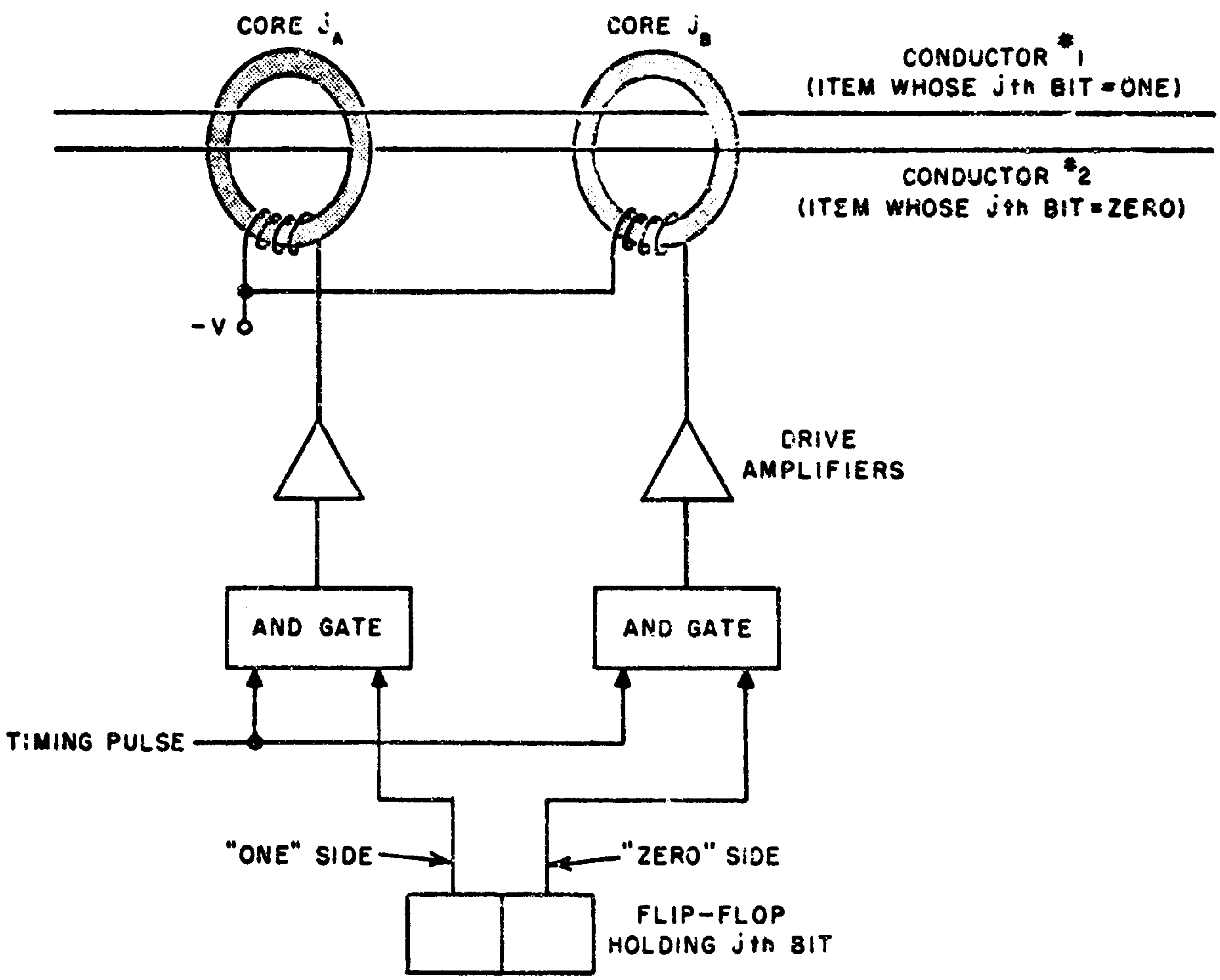


Figure 9. Circuit for Testing Identity

conductor of an item whose j^{th} bit is ONE (conductor #1) bypasses core j_A while the conductor of an item whose j^{th} bit is a ZERO threads core j_A. The threading of core j_B by the two conductors is the reverse of the wiring of core j_A. If the flip-flop stores a ONE, the primary winding of core j_A will be energized when the timing pulse occurs. No voltage will be induced in conductor #1 (a match indication) but a voltage will be induced in conductor #2 (a mismatch indication). If the flip-flop stores a ZERO, the primary winding of core j_B will be energized. In this case, a voltage will be induced in conductor #1 but not in conductor #2. Thus it can be seen that the bit stored in the MIRF must match the test bit identically for a match indication to be obtained.

(2) Relation of MIRF's and the Associative Registers

The major parts of the system are shown in the logical block diagram of Fig. 10. The MIRF units are central to the system. Associated with each MIRF unit is a set of drive amplifiers and a match detector. Information to be gated into a MIRF unit by way of the drive amplifiers is held in flip-flop registers. An interrogation of a MIRF unit consists of applying a particular pattern of drive voltages to the primaries of the cores of the MIRF and observing the output of the match detector. One output voltage level indicates a match between the interrogation and the information contained in the MIRF, and the other output voltage level indicates some degree of mismatch between the two. The output of the match detector is typically used to modify the contents of a flip-flop register.

Consider now the relationship between the document MIRF and the associated flip-flop registers. The document accession number is held in a 17 bit flip-flop register. Both outputs (ONE and ZERO) of each flip-flop are connected to drive amplifiers which in turn are connected to primary windings of cores in the document MIRF. So 34 drive amplifiers and 34 cores are used in the accession number portion. The search code of an input question is held in an 80 bit flip-flop register. The ONE side of each flip-flop is connected to a

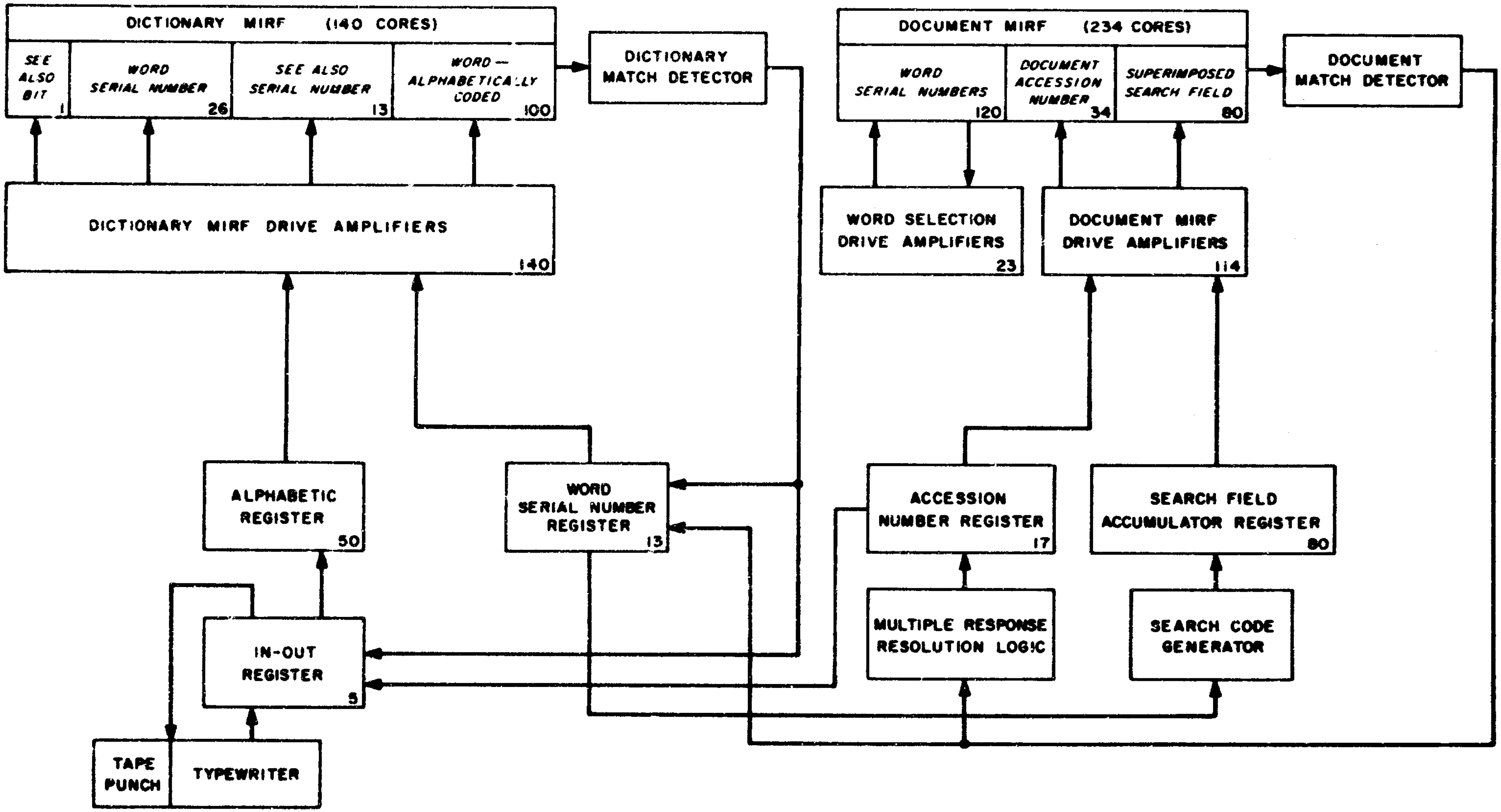


Figure 10. Logical Structure of MIRF Experimental Model (Revised)

C-4110-3-R

drive amplifier which supplies current to the primary winding of a core in the MIRF. Hence, 80 amplifiers and 80 cores are used in the search code portion. The binary serial numbers of words associated with a document are held in a 120 core portion of the document MIRF. The binary serial numbers are never used in an interrogation of the document MIRF and so do not have to be held in an external flip-flop register. For this reason a separate drive amplifier does not have to be associated with each of the 120 cores. The number of drive amplifiers for this section is reduced substantially by using coincident voltage selection of cores. An 8 by 15 selection matrix including 23 drive amplifiers is used.

Next consider the dictionary MIRF. The alphabetic code of an input word is held in a 50 bit flip-flop register. Both the ONE and ZERO sides of each flip-flop is connected to a drive amplifier which is associated with a core in the alphabetic code portion of the MIRF. Thus 100 drive amplifiers and 100 cores are used in the alphabetic portion. The serial number of a word is held in a 13 bit flip-flop register. Again both sides of each flip-flop are connected to drive amplifiers which are connected to primary windings of cores in the MIRF. Therefore 26 drive amplifiers and 26 cores are used in the input word serial number portion of the dictionary MIRF. The serial number of a see-also reference that is associated with an input word is generated by gating the decoded output of a counter to the dictionary MIRF. Thirteen amplifiers and 13 cores in the MIRF are required for this purpose.

(3) Basic Operations Using the MIRF's

Two types of operations involving the MIRFs are basic to the operation of this Document Data Indexing Set. One operation tests to see if certain information is contained in the MIRF. The other uses information that is contained in the MIRF to generate a number in a flip-flop register external to the MIRF proper. Examples of these basic operations are given in the following paragraphs.

(a) Testing of Information Contained in a MIRF

(i) Dictionary MIRF. During the input of English words to form a search question, the dictionary MIRF is tested to see if the input word is contained in the vocabulary (that is, if it is a valid descriptor). This is done by gating the contents of the alphabetic descriptor register to the 100 drive amplifiers associated with the alphabetic portion of the MIRF. As a result, 50 drive amplifiers will be energized and 50 primary windings in the MIRF will carry current. If one of the stored words has a bit pattern in the alphabetic portion that matches the energized set of primaries, the match detector will indicate a match condition. If the two are not identical, the match detector will indicate a mismatch condition. The output of the match detector is used to determine the next step in the logical sequence. It is important to note that the test is applied to the entire dictionary MIRF simultaneously and that a match or mismatch signal for the entire MIRF is obtained in about 5 microseconds.

(ii) Document MIRF. After all words of the search question have been typed, the <u>superposition</u> of their search codes is held in the search code accumulator. At the beginning of the actual search operation the flip-flops of the search code accumulator are gated to their associated drive amplifiers. A particular set of drive amplifiers is energized and current flows in a corresponding set of primary windings in the superimposed

code field of the document MIRF. If the detailed bit pattern represented by the energized primaries is included in any of the superimposed fields of the stored document indexes, a match condition is indicated by the match detector. If not, a mismatch indication is given. The test is made on the entire contents of the document MIRF simultaneously and a YES/NO response is obtained in about 5 microseconds.

It should be pointed out that the criterion for match is inclusion, not identity. A document index includes the search question if the following conditions on the superimposed search code portion of the index are satisfied. First, for every bit of the index search field that is a ONE, the corresponding bit of the search question is either a ZERO or ONE. Second, for every bit of the index search field that is a ZERO the corresponding bit of the search question is a ZERO.(in other words a binary ONE includes both a ONE and a ZERO, but a binary ZERO does not include a binary ONE).

(b) Generating Numbers by the MIRF Process

(i) Dictionary MIRF. The generation of the serial number of a see-also reference illustrates this operation. Assume that an English word having a see-also reference has been typed in and that the test for valid descriptor is true. The fact that a match is obtained when the alphabetic descriptor register is gated to the MIRF effectively isolates one line in the dictionary MIRF. By gating the alphabetic descriptor register to the MIRF and at the same time

causing current to flow in the primary winding of a core that is outside the alphabetic code portion of the MIRF, the binary value associated with that core for the selected line can be determined. The presence of current in the additional winding tests for a binary ONE in that position. If the match detector indicates a match, the value is indeed ONE. However if a mismatch is obtained, the value must be ZERO. So the sequence for generating the serial number of a see-also reference is as follows. First the flip-flop register that will eventually hold the serial number is cleared to all ONEs. Then the alphabetic descriptor register is gated to its drive amplifiers and a drive amplifier associated with the parity bit of the serial number is energized. The output of the match detector is observed. If a match condition is observed, it is known that the parity bit is actually a ONE and the parity bit flip-flop in the serial number register is not changed. If a mismatch is observed it is known that the parity bit is ZERO and the parity bit flip-flop in the serial number register is changed to ZERO. The next step is to energize the drivers associated with the alphabetic descriptor register and a driver associated with the least significant bit of the serial number. Again the output of the match detector is observed and the flip-flop assigned to the least significant bit is either allowed to stay at ONE or is changed to a ZERO. This procedure continues for 13 steps. At the end of this

time the 12 bit serial number and its parity bit will have been generated and stored in the serial number register.

(ii) Document MIRF. The generation of serial numbers of words contained in responding document indexes is similar to the procedure just described. In this case the accession number register drivers and a driver that corresponds to a particular bit in the word serial number portion of the document MIRF are energized. Before the sequence begins the serial number register is cleared to all ONEs. The first step is to determine the value of the parity bit by gating the accession number register number and the proper circuits in the word selection matrix. The output of the document match detector is observed and the parity flip-flop of the serial number register is left at ONE or changed to ZERO depending upon whether the match detector output is a match or a mismatch. The remaining par^ of the word serial number is generated in twelve successive steps.

C. Circuit Design

(1) Introduction

Three principal types of transistor circuits are used in the document data indexing set: transistors used as switches to drive the primary windings of the MIRF cores, descriminator-amplifier circuits to accept the voltage generated on the secondary windings of the MIRF cores (this is the match detector circuit) and transistor logic circuits for the over-all control of the MIRF operations. It was decided to design all three types at SRI. The first two are special circuits and could not be bought from commercial suppliers. Logic circuits

could be bought from outside suppliers but it was believed that a superior and less expensive job could be done by retaining the design in our laboratory. Excellent performance of logic circuits during the checkout of the experimental equipment has verified this position.

(2) Logic Circuits

(a) Selection of Basic Circuit. Two types of transistor logic circuits were considered intensively for the MIRF system. The first was diode transistor logic (DTL), and the second was resistor-transistor logic (RTL). Both types have found extensive use in commercial computing equipment either separately or in compatible association. Both types have unique advantages and disadvantages which were carefully weighed in choosing a circuit type for the MIRF system. The decision to use RTL was based primarily on the cost advantage which it provides in this particular system at the relatively slow speeds involved. Let us consider each type of logic system in some detail to see how this cost advantage is obtained.

A typical diode transistor logic circuit is shown in Fig. 11-A. A circuit of this type was used, for example, in the Air Force ULD-1 system, portions of which were designed at SRI in 1959. The RTL circuit designed for the MIRF system is shown in Fig. 11-B. DTL circuits have several notable advantages over RTL circuits, chiefly the following. For a given operating speed, the gain-bandwidth product required of the transistor is much less than that required in the RTL circuit. This speed advantage arises primarily because of the speed-up capacitor which is used in the DTL

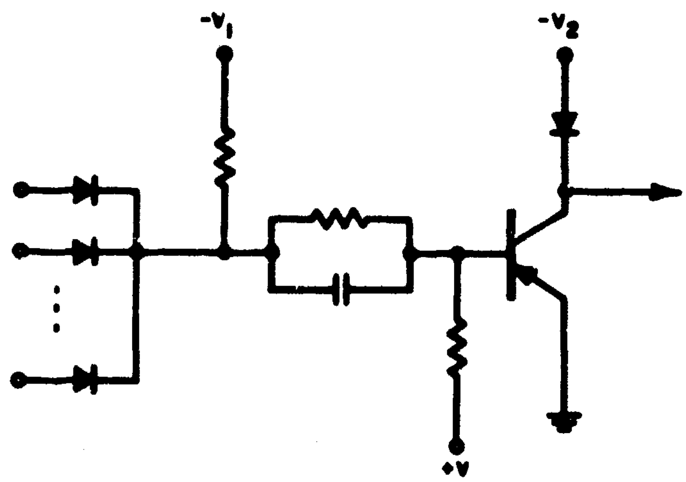


Figure 11A. A Typical DTL Circuit

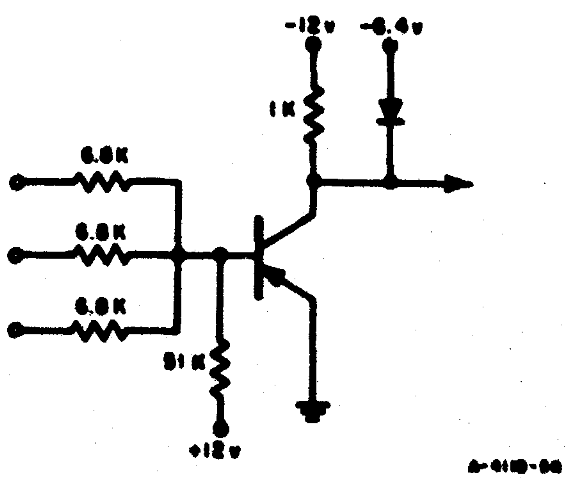


Figure 11B. The RTL Circuit Designed for the MIRF System

case. Secondly, the excellent isolation provided by the input diodes, rather than input resistors, permits very large fan-ins to be realized in DTL. The worst-case fan-in, for a given fan-out, is actually so large that it is not useful. However, the excessive fan-in can be traded for relaxed tolerances on resistors, power supplies, and devices. This trade-off makes the unit cost on parts and devices for the DTL circuit relatively low. The cost of a diode, however, is still greater than the cost of an input resistor, so that at least a portion of the cost advantage of DTL using conventional components is offset.

At this point it appears that DTL circuits are more economical than RTL. If we were to assemble the MIRF logic cards out of conventional components on a standard pointed circuit board, such a conclusion would be correct. For the RTL circuit one is forced to purchase a higher-speed transistor (at higher cost), and to impose more stringent tolerances on the components (again at higher cost) in order to achieve equivalent performance and reliability. If one considers non-conventional components, however, the situation is entirely different. We are able to purchase all the passive components shown in Fig. 11-B, plus some additional capacitors and resistors for making flip-flops and shift registers, for only $0.50. These components are screened on a passive substrate to a tolerance of 3% for the resistors (5% design tolerance) and 10% for the capacitors. The substrates are encapsulated with a durex coating, and are ready for mounting to a printed circuit card via their projecting leads.

Mechanical and electrical specifications of the element used in the logic circuits are shown in Fig. 12. The economy of the passive substrate approach is such that even the added cost of a higher-frequency transistor is more than compensated. Total component cost of the RTL circuit is approximately 85% that of the DTL circuit. In addition, further economies are obtained because of the time saving obtained in mounting a single substrate rather than a large number of individual components to the printed circuit board.

It must be emphasized that no sacrifices were made in operating speed or potential reliability of the final circuitry. Since the operating frequency of the MIRF system is relatively low (50 kc) a suitable transistor is available (the 2N2401) which is easily capable of 100 kc and higher frequencies, even with RTL circuitry. Reliability is essentially equivalent in the two circuits, worst-case design procedure being applied in both instances. In fact, the somewhat better reliability figures for resistors over diodes implies a minor advantage for the RTL circuit.

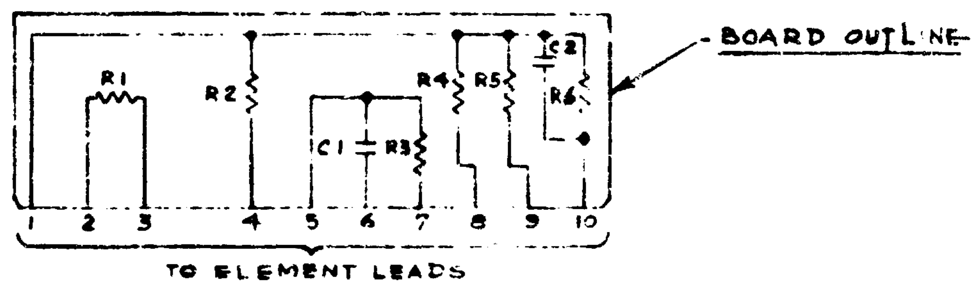
(b) Basic Gate Circuit.

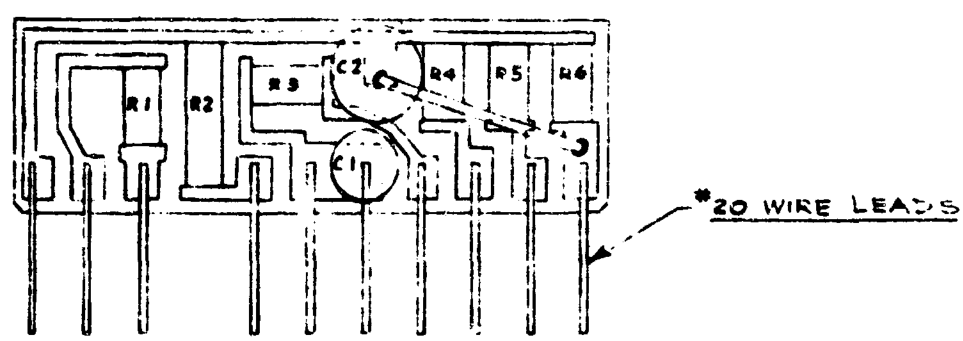
The basic gate circuit is shown in Figure 12. This circuit in typical use performs a simple majority operation. If one or more of its three inputs are at a negative potential, the output is held at ground potential. Since ground is defined as the one stage in this system and a negative six volt potential is defined as a zero state, the basic gate performs the "not and" or NAND operation.

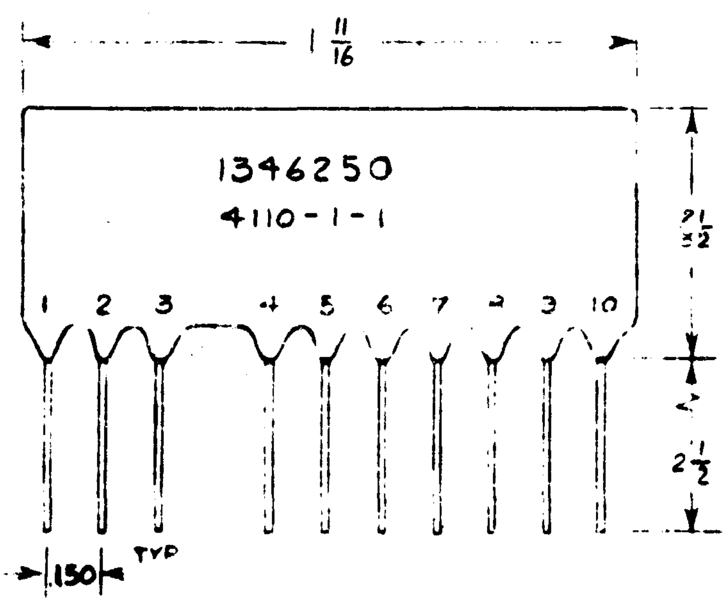
The gate circuit is a basic part of every logic circuit employed in the machine. By itself it performs the

NOTES:

1. REMOVE ALL BURRS AND BREAK SHARP EDGES APPROX. .010R.
2. GENERAL FINISH √, EXCEPT AS NOTED.



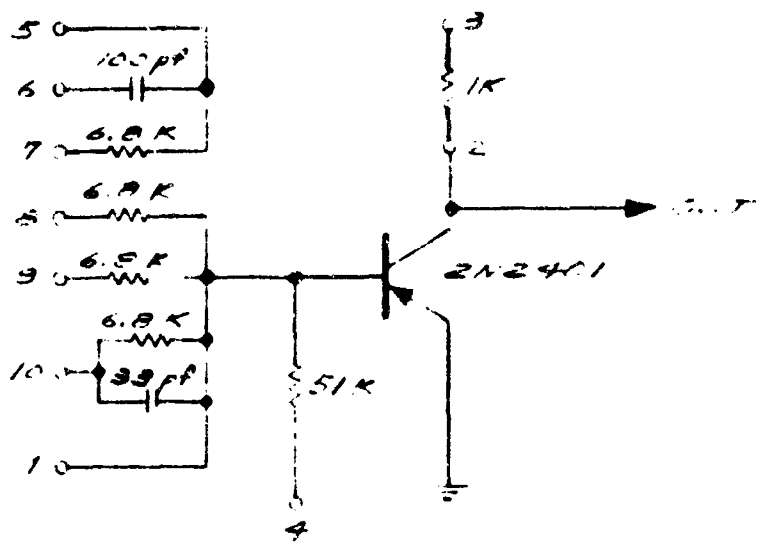




PREPARED UNDER CONTRACT
AF 30 (602)-2772

B-4110-2001

ISSUE



BASIC NAND GATE

COMPONENTS

R1 = 1K ± 5%
R2 = 51K ± 5%
R3 = 6.8K ± 5%
R4 = 6.8K ± 5%
R5 = 6.8K ± 5%
R6 = 6.8K ± 5%

C1 = 100 $\mu\mu f$ ± 10%
C2 = 33 $\mu\mu f$ ± 10%

ITEM	DWG. NUMBER	DESCRIPTION	QTY.

MAT'L:

PROCESS:

TOLERANCES: UNLESS OTHERWISE SPECIFIED	BASIC DIMS.	FRACT. TOL.	DECIMAL TOL.
	0 TO ½	± 1/128	± .003
	½ TO 6	± 1/64	± .005
ANGULAR TOL: ± ½°	6 TO 24	± 1/32	± .010
	ABOVE 24	± 1/16	± .015

DR. [illegible] 1-8-64

CKD.

APPD.

APPD.

TITLE: BASIC CENTRAL AB UNIT

NEXT ASSEMBLY:

SCALE: 2:1

CONTRACT
772

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIF.

DWG. NO. B-4110-2001

ISSUE

Fig. 12

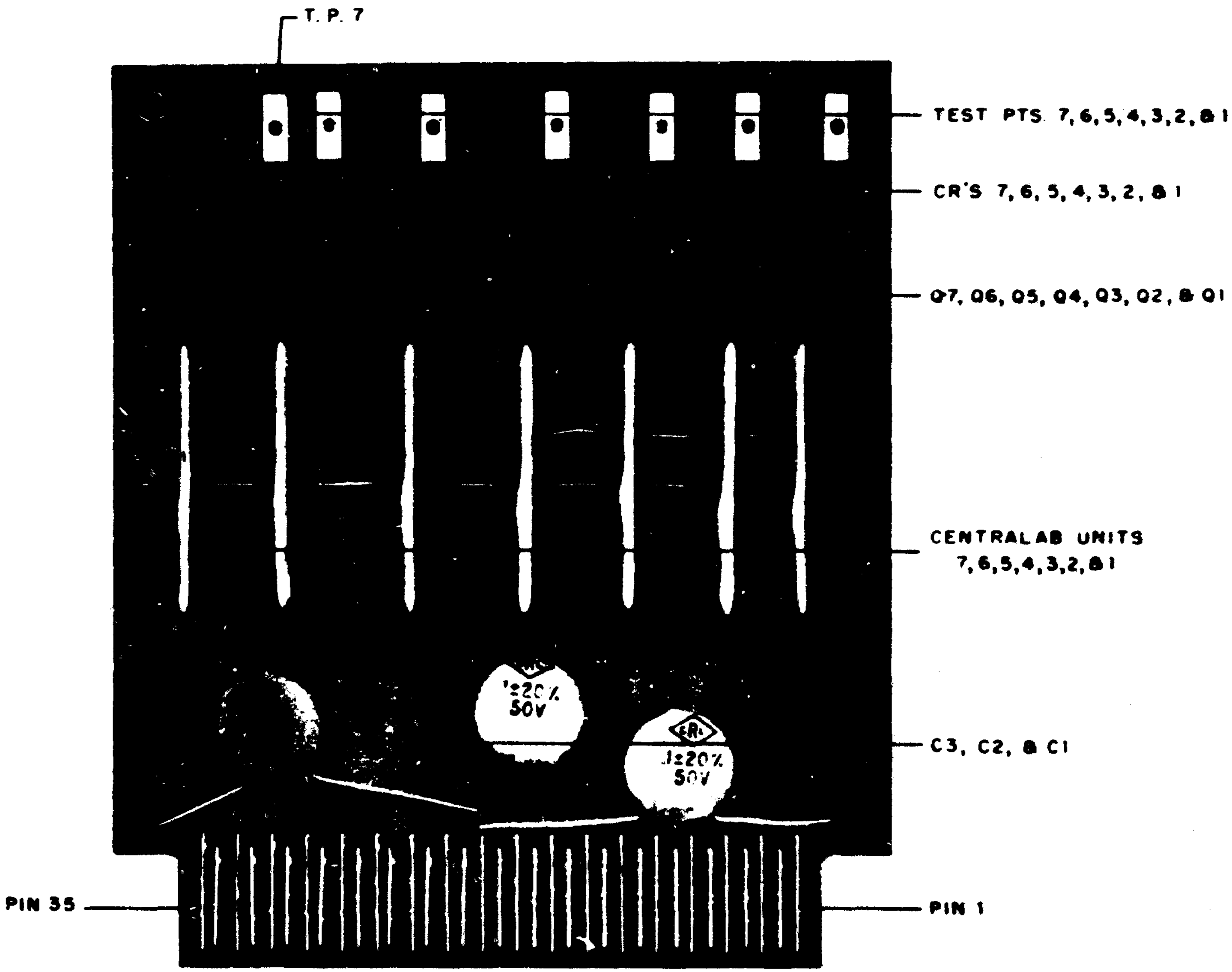
combinatorial function of logical conditions. Two gate circuits properly interconnected form a bistable, or flip-flop, circuit. Two gate circuits interconnected in a slightly different way form a monostable, or one shot, circuit. The gate circuit is also used as a preamplifier for an emitter follower circuit. The basic logical circuits, gates, one shots, flip-flops, etc. are combined in optimum fashion and mounted on plug-in logic boards. The circuit boards used in the Data Indexing Set are described in the following paragraphs.

(c) Gate Board. Seven gate circuits are mounted on a printed circuit board to form the gate logic board (see Fig. 13). Three of the gate circuits have a special feature in that the collector resistor of the gate transistor is not connected to the minus twelve volt supply. Using these gates a circuit having six, nine, or any multiple of three up to fifteen inputs can be constructed.

(d) Three flip-flop circuits are mounted on one board as shown by Fig. 14.

(e) Shift register board. Six flip-flop circuits with special interconnections are mounted on a printed circuit board to form the shift register logic board (see Fig. 15). Printed circuit wiring on the board connects four of the flip-flops to make a four-stage shift register. Printed wiring also connects two flip-flops independently to form a two-stage shift register.

(f) One shot board. Four one-shot circuits are mounted on the board shown in Fig. 16. Four gate circuits are also mounted on this board to provide inversion of signals into or out of the one-shot circuits. It should be pointed out that the



NOTE:
ALL COMPONENT NUMBERS
READ FROM LEFT TO RIGHT

P-4110-3002

Figure 13. Component Assembly of Gate Logic Board

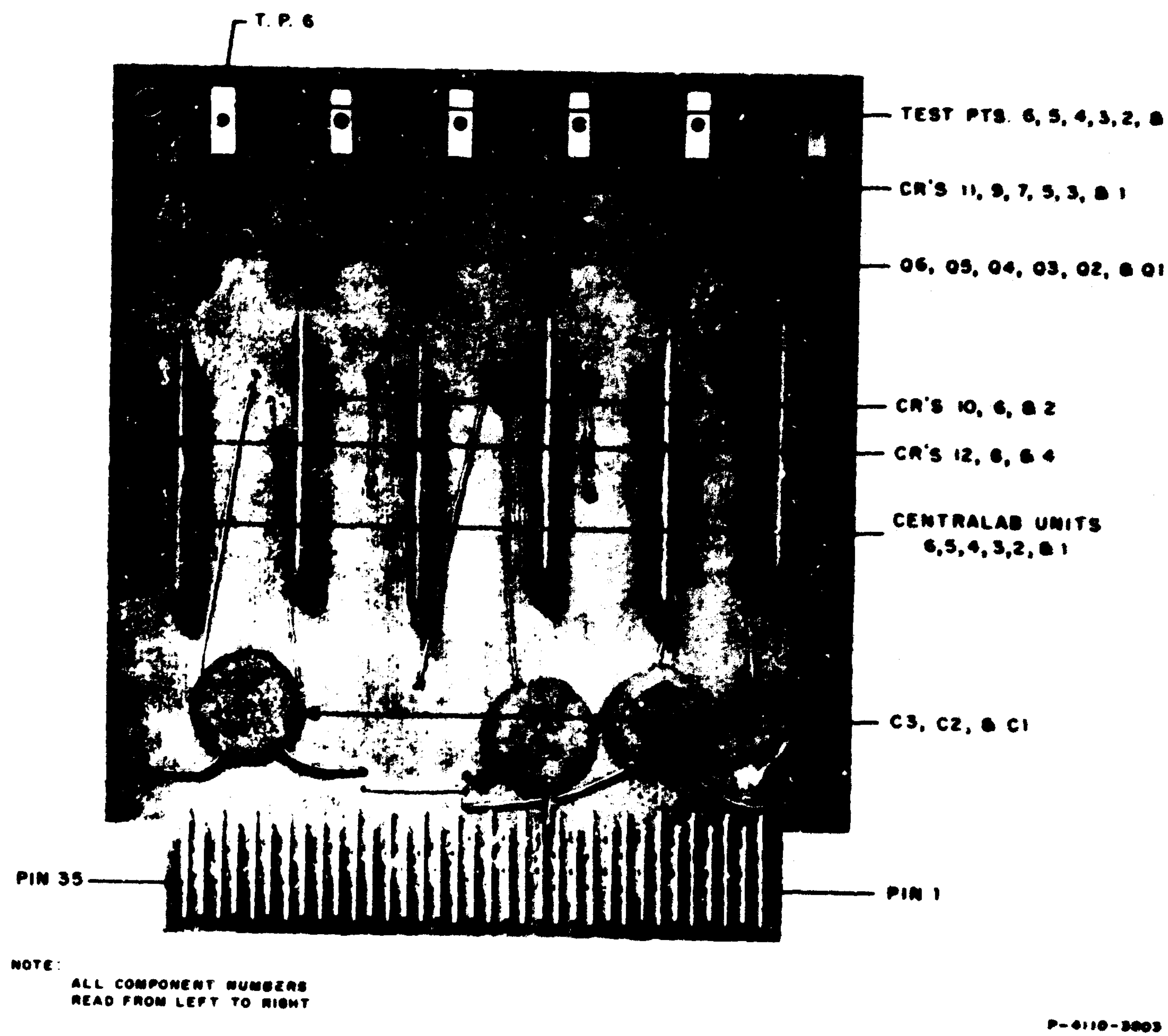


Figure 14. Component Assembly of Flip-Flop Logic Board

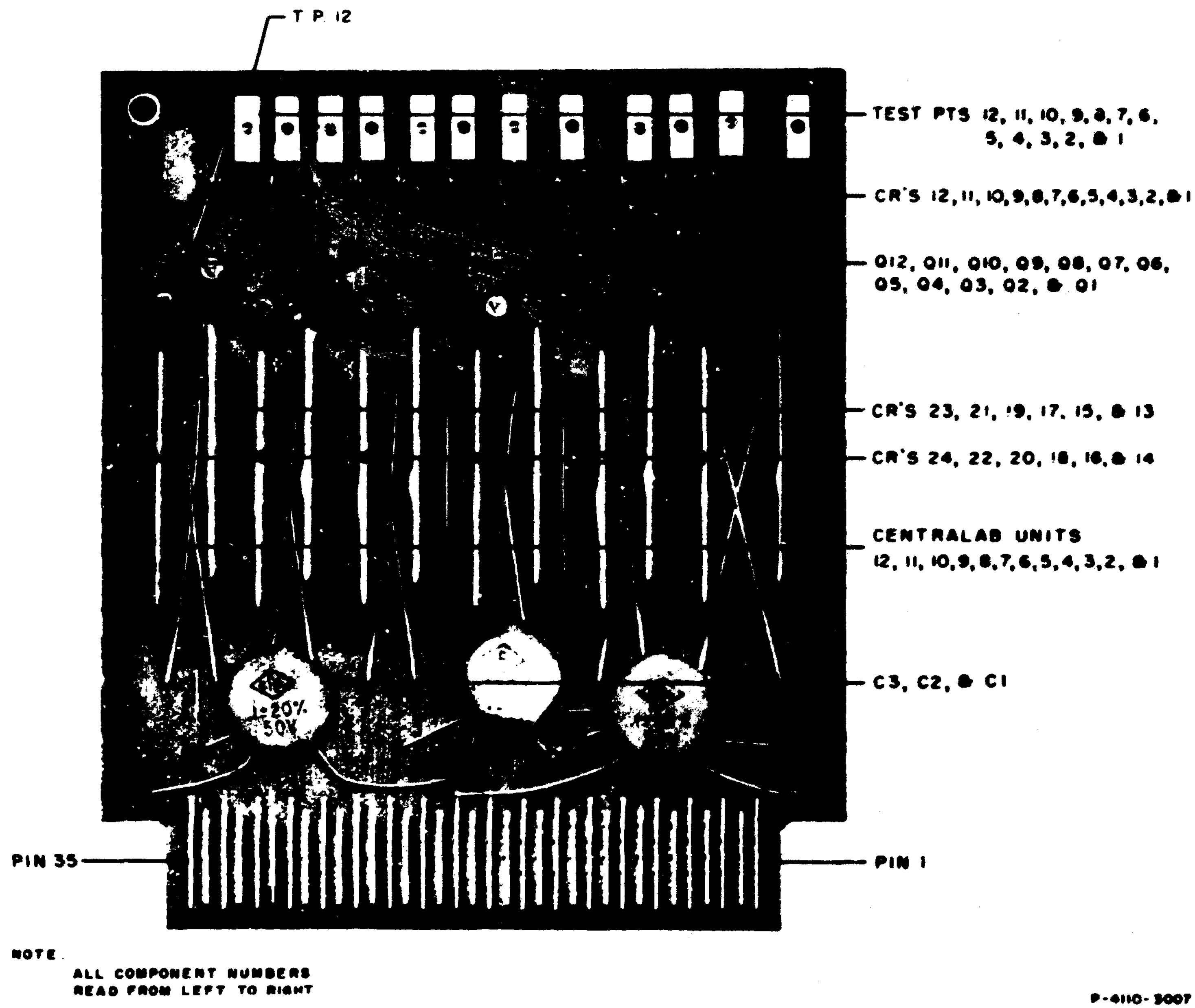


Figure 15. Component Assembly of Shift Register Logic Board

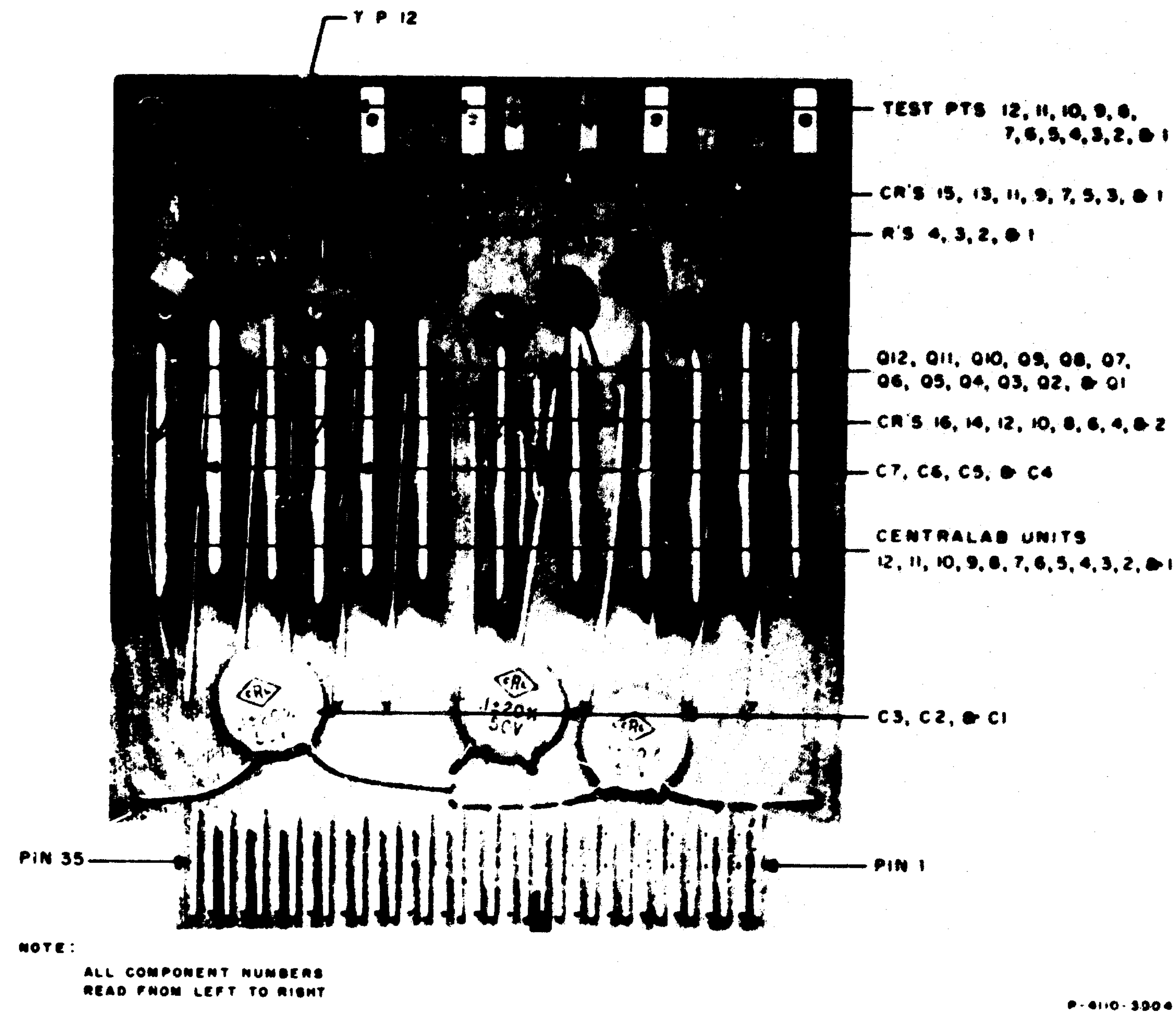


Figure 16. Component Assembly of One Shot Logic Board

number of inputs on the gates of the one-shot board is two, rather than three for all other gates.

(g) Emitter follower board. Four emitter follower circuits are mounted on the board shown in Fig. 17. The standard logic gate that forms a driver to the emitter follower circuit is not permanently connected to the emitter follower. The logic design rules permit a gate to drive more than one emitter follower circuit. It may be wired to as many as four emitter follower circuits. Furthermore the gates on the emitter follower card may be used as standard gate circuits (that is their outputs do not necessarily connect to an emitter follower circuit). An emitter follower circuit can drive many more loads than a gate, namely, 20 loads as compared with five for a standard gate circuit.

(2) Other Circuits

(a) System clock. The 50 kc clock used and distributed throughout the entire logic portion of the machine is generated by a free running emitter coupled multi-vibrator. Two transistors constitute the basic multi-vibrator which couples out at standard logic levels through a third transistor. Another transistor is used to permit the clock to be gated on or off. The ability to shut off the clock is quite useful in preventing damage to the MIRF drivers and components in the magnetic MIRF circuits. The clock board is shown in Fig. 18.

(b) MIRF driver. The ferrite cores used in the document and dictionary MIRFs require drive currents of nearly two amperes per line. Four MIRF driver circuits are mounted on one printed circuit plug-in board as shown in Fig. 19. Each

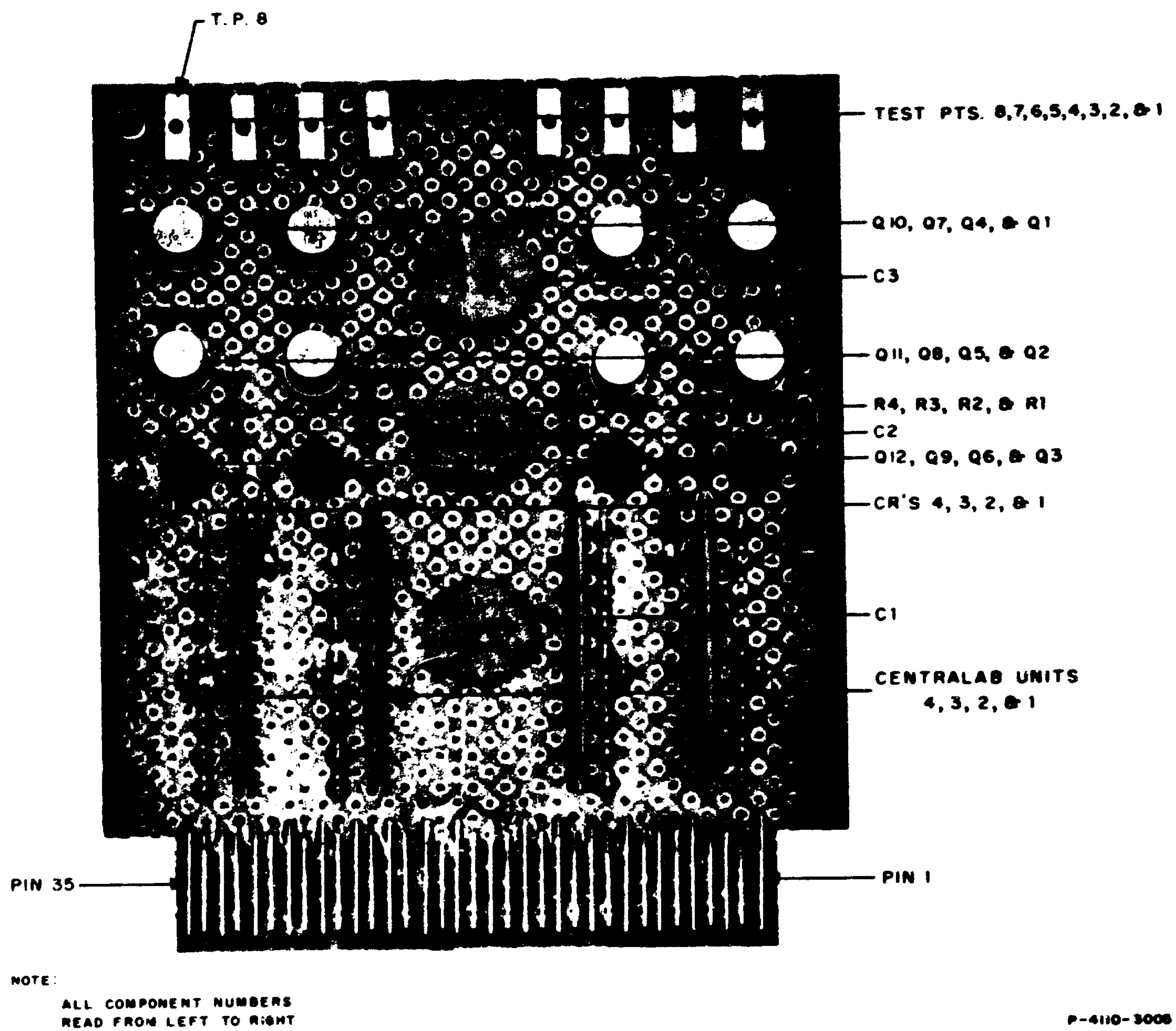


Figure 17. Component Assembly of Emitter Follower Board

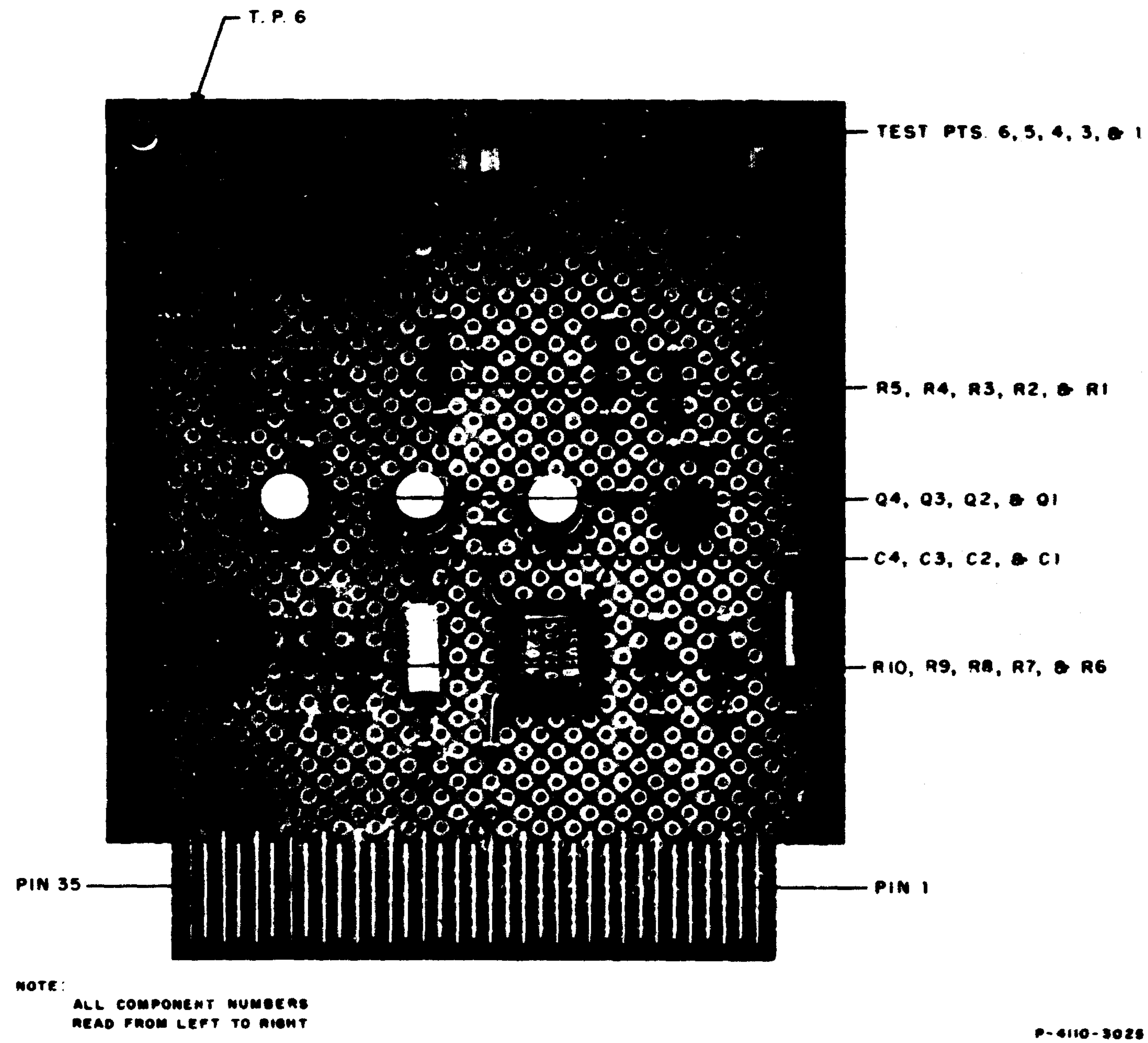


Figure 18. Component Assembly of MIRF Clock System Board

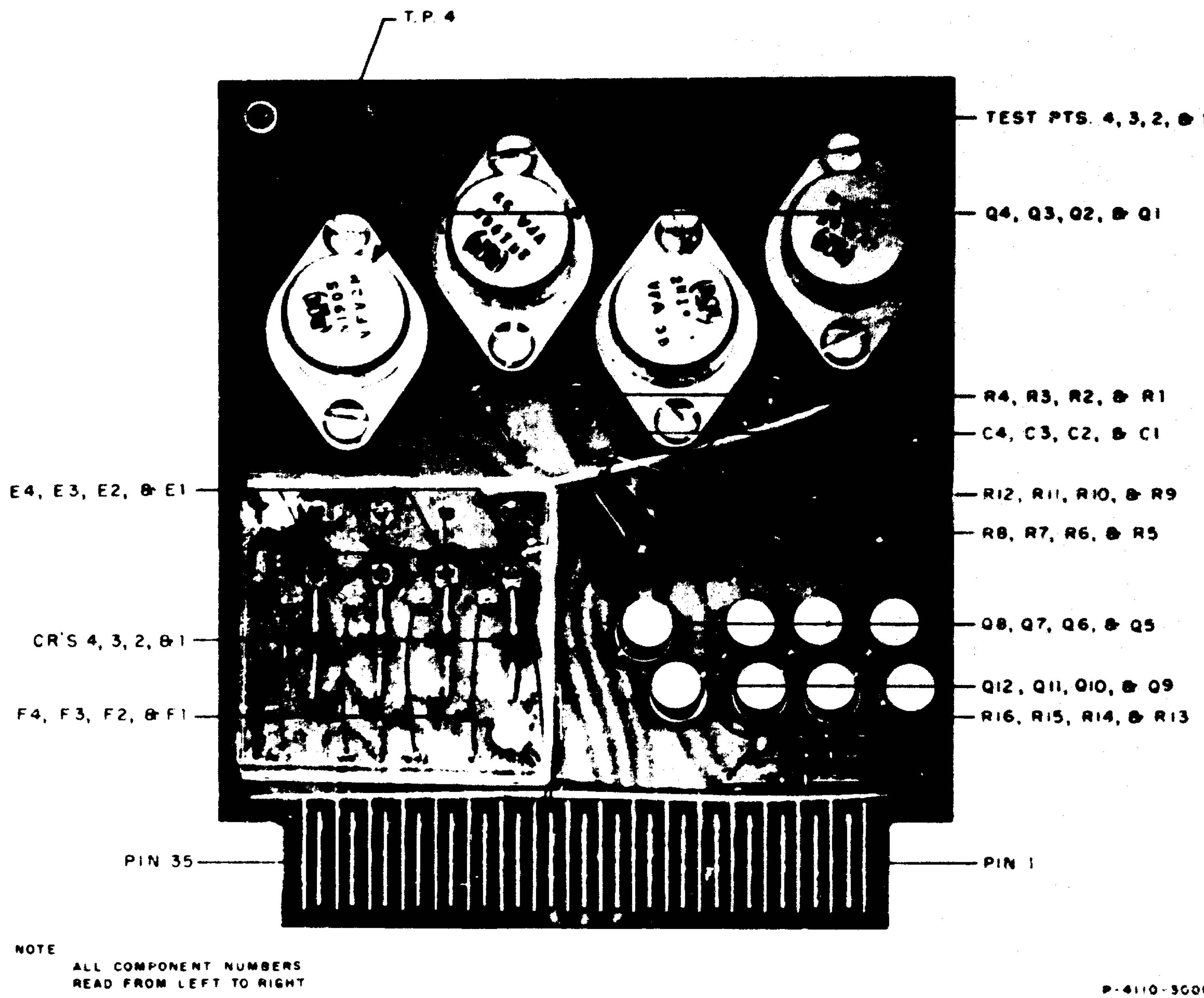


Figure 19. Component Assembly of MIRF Driver Board

circuit is capable of supplying the required two amperes at low impedance. The power transistor that delivers the drive current (Type 2N1905) is driven by a push-pull emitter follower that provides 60 milli-amperes of base drive current into the 2N1905. The output power transistor has rise and fall time capabilities of less than 0.3 microseconds. The actual current in the load is nearly linear because of the inductive nature of the load and builds up to the two-ampere amplitude at the end of approximately 10 microseconds. The over-shoot voltage induced when the transistor is turned off is clamped by a silicon diode to -36 volts. The clamp prevents excessive voltage spikes from appearing across the output transistor while still allowing the load inductance to recover within 10 microseconds.

Two protective features of the MIRF driver circuit should be noted. One is a fuse which is inserted in series with the load to protect against excessive load currents. Before the windings of the magnetic circuits internal to the MIRF assembly can be damaged by an over current, the fuse wire will open up. The second protective circuit includes a square loop memory core that is threaded by the lead going to the transistor load. This core is normally biased off, but if the drive current exceeds a safe value the square loop core will switch and induce a voltage in a sense lead. The voltage in the sense lead is amplified and used to turn off the system clock. The purpose of this circuit is to protect the 2N1905 transistor against excessive heat dissipation.

(c) Split switch driver board. Four circuits that are similar to the MIRF driver circuits are mounted on a special board shown in Fig. 20. The split switch driver circuit is always used in conjunction with a MIRF driver circuit and effectively connects between the output terminal of the MIRF load and the power supply. By using the two circuits, specific cores in the core array of the MIRF module can be selected on a "coincident voltage" basis.

(d) Source and drain circuits. Selection currents to a coincident current magnetic core memory that is used for scratch pad storage in the system are provided by the source and drain circuits. The coordinate address leads in the core memory are selected on the coincident voltage basis as follows. The source circuit delivers a current of 180 milli-amperes to a selected group of memory drive lines. The drain circuit conducts this current from one line of the group to ground. By proper selection of source and drain current drivers, current can be steered through any selected line of the memory. The source circuits contain a 56 ohm collector limiting resistor while the drain circuits have no collector load resistor. These circuits are intended to deliver half select currents to the memory for periods of six to ten microseconds. A plug-in board on which four source and four drain circuits are mounted is shown in Fig. 21.

(e) MIRF discriminating amplifier. The electrical output of the MIRF magnetic modules is generated by a very large diode gate including almost 300 diodes. Under the worst conditions a match signal from this array can reach a level as high as 0.4 volts. On the other hand, a mismatch signal from

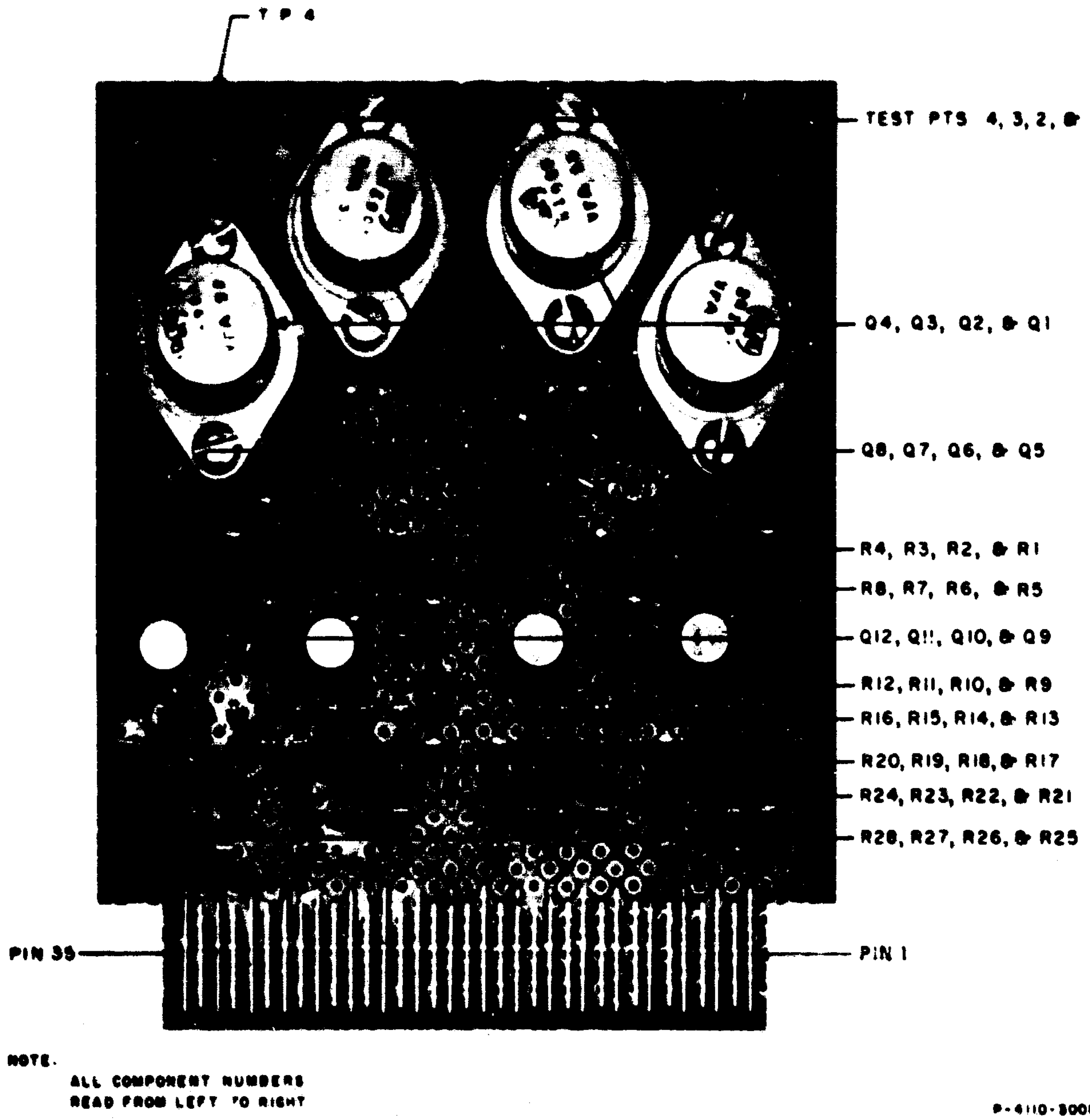


Figure 20. Component Assembly of Split Switch Driver Board

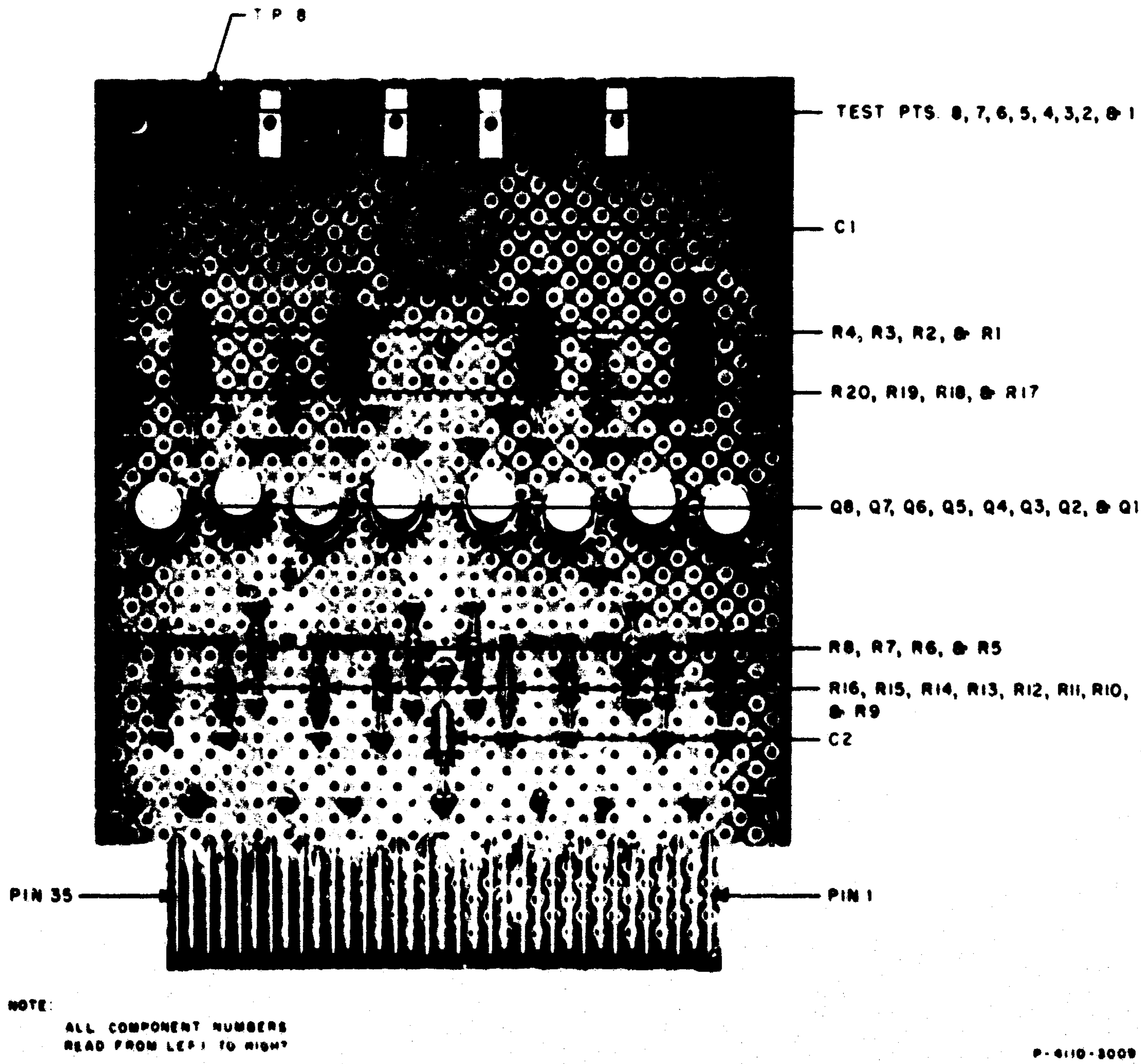


Figure 21. Component Assembly of Source and Drain Logic Board

the same array under worst conditions may only generate a potential of 0.6 volts. It is necessary for the MIRF discriminating amplifier to differentiate between these two signals and generate a standard logic level output of -6 volts for a mismatch and 0 volts for a match. In order to distinguish between very closely spaced match and mismatch signals two thresholds are employed in the amplifier. The first threshold is provided by a 1N3605 silicon diode at the input to the amplifier. This diode does not pass signals unless they exceed approximately 0.5 volts. After passing the first threshold the signal is amplified in a feedback amplifier with a gain of about 50. If the amplified signal then exceeds the second threshold of 3 volts, a mismatch signal is delivered at the output of the amplifier.

(f) Core memory sense amplifier. The sense output of the coincident current scratch pad memory is typically a 50 millivolt bi-polar pulse. These pulses must be detected and restored to standard logic levels. In the sense amplifier the input signal is applied to a five to one step-up transformer with a special center tab and ground shield to provide high common mode noise rejection. The input transistor amplifies the signal by a factor of five and applies it to a full wave bridge rectifier through a one to one transformer. The bridge rectifies the bi-polar signal and simultaneously rejects any signals which do not exceed the diode threshold. If the threshold is exceeded, the output transistor conducts and a ground level is produced at the output terminals.

D.

(g) MIRF error sensing amplifier. A small square loop memory core is associated with the output lead of each MIRF driver. The purpose of the MIRF error sensing amplifier is to amplify a voltage induced in the sense lead of the square loop core in case of an excessive drive current. This amplifier is quite similar to the discriminating amplifier. The major difference is that the error sensing amplifier does not have the input threshold diode that is used in the MIRF discriminating amplifier. The output of the error sensing amplifier is used to set the clock control flip-flops to a state in which the clock pulses are turned off.

(h) Circuit for detecting excessive number of MIRF gate pulses. This protective circuit insures that the number of consecutive gating pulses that is applied to the MIRF modules is not excessive. The basic parts of the circuit are an integrator and a Schmidt trigger. Input pulses are amplified and inverted by the first transistor stage and are integrated in the 0.33 microfarad capacitor. When about 200 pulses have been received by the circuit, the voltage developed on the integrating capacitor reaches the threshold (3 volts) of the Schmidt trigger and a single output pulse is generated. This output pulse sets the clock control flip-flop to the state that turns off the clock. The integrating circuit always completely recovers in less than 100 milliseconds so that normal operations of the MIRF magnetic circuits are not interrupted. This circuit is required because too long continued pulsing of the MIRF magnetic circuits will cause damage to the components of the magnetic circuits and overload the power supply.

Magnetic Design

(1) General Considerations

The magnetic design of a MIRF unit is centered in the individual magnetic core. Each core acts as a transformer with a multi-turn primary winding and many single turn secondary windings. When current flows in the primary winding the magnetic core must be capable of producing a flux change of sufficient time duration and amplitude to generate the desired signal in secondary windings. The amplitude of the induced voltage is determined primarily by the characteristics of the diode associated with the secondary winding. The duration of the induced voltage is determined primarily by noise on the secondary winding and the delay required before sampling of the output can be accomplished.

The cross sectional area of the magnetic core is proportional to the product of the amplitude and duration of the voltage induced in the secondary windings (this is usually referred to as the volt-second area of the induced voltage pulse). This was kept reasonably small by using a high quality germanium diode which requires a back biasing voltage of only .6 of a volt in order to perform properly in the diode circuit associated with the input to the discriminating amplifier. The circumferential length of the magnetic core is determined primarily by the number of secondary windings associated with the core and the mechanical design of the supports for these windings. In the MIRF units of the experimental equipment the core has the capacity for 2,000 secondary windings. The core's mean circumferential length is seven inches; its cross-section is a square, one quarter inch on a side.

Two other considerations influenced the selection of the magnetic cores used in the MIRF units. One is the requirement that the core be made in two pieces so that the array of cores can be separated into two portions to facilitate initial wiring and changes in wiring. The other is the necessity of using commercially available parts. The number of cores needed in this experimental equipment is too small to justify the design and production of a core of special size or shape.

(2) Details of the Dictionary and Document MIRF Units

The individual cores used are the same for both the dictionary

and the document MIRF. The only difference between the two magnetic structures is in the number of cores and the wired information patterns. 140 cores are used in the dictionary and 234 cores in the document MIRF. Each core is composed of two "U" shaped structures. These parts are Allen Bradley part no. UC 892-141C which have been specially modified at the factory to produce a maximum of .0005" air gap in each leg when two such structures are joined together to produce a MIRF core. To drive each core a twenty turn primary winding is provided. This consists of two ten turn distributed windings each wound on a fish paper bobbin or coil form. These windings are distributed in such a manner as to minimize the leakage flux and the resulting noise signal therefrom. There is also a bias winding which consists of one turn mounted on the base plate or bottom tray which supports the primary bobbins. This winding will apply two ampere-turns to each core. The primary winding will drive the core from an 18 volt voltage source through a transistor switch driver. This allows for a 2 volt drop in the wiring resistance and the drop across the transistor. The output voltage then which is induced upon each secondary winding (each is a single turn winding) is an essentially rectangular voltage pulse having a drop of .1 volt in ten microseconds, from .8 volts at the leading edge to .7 volts just prior to the trailing edge. The maximum MMF applied to the core through the primary is fourteen ampere-turns (.7 amperes) and this occurs at ten microseconds after the beginning of the pulse. To accommodate the expanded capacity of the MIRF model (5,000 documents and 3,000 dictionary words) three primary windings will be driven in parallel for the file and two in parallel for the dictionary. The maximum driver current required from the file drivers is seen to be 2.1 amperes, and for the dictionary 1.4 ampere. A transistor protection circuit is provided which will produce an alarm signal if the collector current of the transistor reaches 2.5 amperes. This condition obtains when the total air gap in a given core increases by about 3 times or each of the air gaps in all three cores connected to a given driver increase by a factor of about 2.

The design objectives for the two magnetic MIRF structures were: to limit the noise signal due to leakage flux when all driven cores to .1 volt, and to damp out the transient noise signal within the first 1-1/2 μsec. Meeting these design objectives will insure that the minimum voltage developed on a line which threads a core, i.e., a false reponse is .6 volts and the maximum signal on an unthreaded line, i.e., a true reponse, is .1 volt after first 1-1/2 μseconds and up to the end of the output period 8-1/2 μseconds later. This then provides a minimum signal to noise ratio of 6:1 for each document line. For reasons of efficiency of sense amplifiers the outputs of many document lines are connected to the load through an isolating diode cluster viz., 286 diodes. The sense of the diodes is such as to maintain the voltage across the load at ground potential only in the case when one or more input document lines have only the noise voltage induced thereon. This is the case of one- or multiple-true reponses. The worst case (from a design consideration) is at the higher temp.rature limit e.g., 50°C., where the diode leakage current is a maximum and for the case of a single true response, the total leakage current of all diodes passes through the one diode giving a rise to a large forward voltage drop vis., .45 volts maximum. The worst case (again from a design considera ion) which produces the minimum false signal occurs when a large number of document lines have but a single induced voltage on them (this means the voltage induced by threading a single core). Here, there is a small total diode current i.e., the current required to flow through the load resistor to drop the gate supply voltage less this single induced voltage across it, and so only a portion of this current is carried by each diode; thus the forward voltage drop across the diodes is negligibly small. The minimum false signal across the load resistor being .6 volts. The signal to noise ratio at the output of the diode gate then is 1.33:1.

In operation of a small breadboard model it was found that the primary winding and the associated capacity of the coaxial cable together with the output capacity of the transistor formed a high Q resonant circuit. These circuits which are intercoupled through the complex wiring pattern and interwinding capacity become shock excited when so coupled to a core which was driven. This output then appeared

on the output of the document lines linking such cores. It was further found that the frequency of this noise signal was a function of the number of cores linked by the document wires, and the amplitude was a function of the number of cores driven. In the small model--which contained 10 cores but the full length (15') of document wiring for 22 documents--the ringing frequency was observed to be as low as 500 kc and the amplitude with 7 cores driven was a .2 volts after 2 μsec. It is clear that such a magnitude of noise would prevent detection of a correct true reponse 1-1/2 μsec after the output pulse leading edge, and it would be aggravated in the full size system.

An effective solution is the combination of a resistor in parallel with the primary winding to damp the circuit and a diode in series with the primary to decouple the line capacitance. By inserting a diode in series with the drive winding and physically close to it, the capacity is reduced to a minimum value and is independent of the method of and variable length in the wiring to the core drivers. This results in a high ringing frequency which requires only a 1000 ohm resistor in shunt with the winding to cause the circuit to have a Q of less than 1/2 at its natural resonant frequency which is the condition for an overdamped circuit. This modification then effectively eliminates ringing currents in the primary winding.

In the breadboard model there was also a noise signal of about 5 mc which is attributable to the inductance and capacitances of the document wires. The frequency of this noise signal is essentially independent of the number of cores in the model but its amplitude is dependent upon the number of cores driven. A parallel tuned circuit tuned to the ringing frequency and inserted in series with the gate load resistor has proven effective in reducing this noise signal to a very low value within 1 μsec following the leading edge of the output pulse. This type of noise was negligible in the full scale MIRF and no filtering was done at the input to the discriminating amplifier.

(3) Analysis of Effects of Inter-Item Capacitance on Drive Circuit Requirements

The magnetic portions of the MIRF experimental model (the Document and

Dictionary files) consist of sets of magnetic cores with the following characteristics: each core has a separate primary (or drive) winding, and each core is associated with many (1000) single-turn secondary windings. The secondary windings pass through or around all cores in the set* and so form a long "rope." Because wires in this rope lie close together over considerable distances, significant capacitance exists between them. When a core is energized by its associated driver, a voltage will be induced in those secondary wires that thread the energized core. Therefore, a potential difference will exist between the secondaries that thread the core and those that do not, and capacitive currents will flow.

The purpose of this analysis is to show the effect of such capacitive currents on the requirements for the driver circuit connected to the primary winding of the MIRF cores. To examine the effect of capacitive currents in a simplified case, consider a single pair of secondary windings and three associated cores, as shown in Fig. 22-A. On the left side of the cores, the windings are connected to a common bus, and on the right they extend a considerable distance so that a substantial capacitance exists between them (shown as a lumped capacitance). If Core A is energized, a potential difference will be developed between Winding #1 and #2, and a capacitive current will flow in Windings #1 and #2. Notice that the effect of the current depends upon wiring patterns of the two windings: at Core A, the capacitive current is in the direction to oppose a primary drive current; at Core B, it would aid a primary current, and at Core C, there would be no net effect because both windings thread the core. The magnitude of the current depends on the voltage developed between the two windings and the capacitance between them.

In the MIRF experimental model, the analysis of inter-item capacitance is much more complex because there are many cores, many secondary windings, and a unique wiring pattern for each secondary. An exact analysis is complicated by two other factors: (1) the result of the analysis should be valid for a fully expanded

---

* Each wire's pattern is unique and is determined by the detailed digital structure of the item the wire represents.

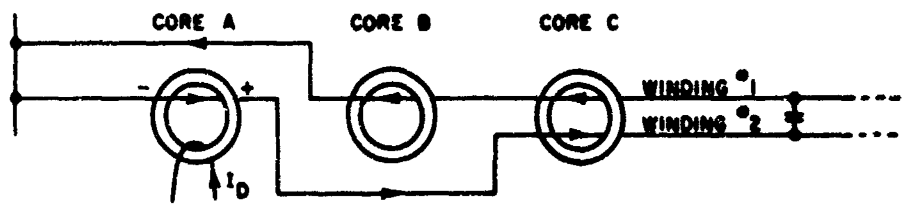


Figure 22. Simplified Example of Inter-Item Capacitance

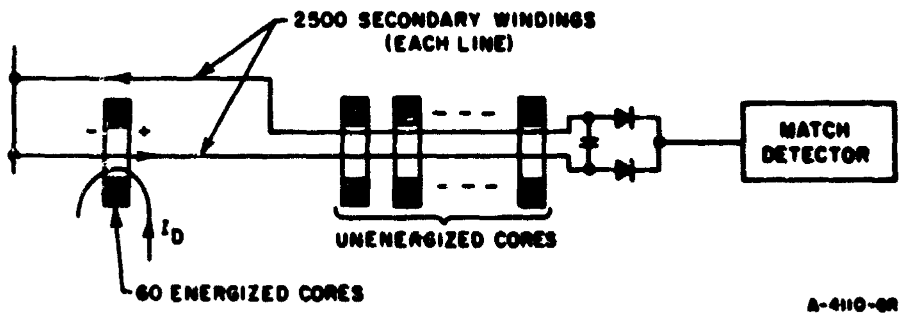


Figure 23. Worst-Case Model for MIRF Analysis

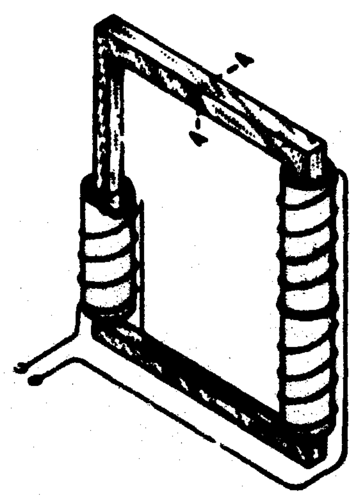


Figure 24. Detail of Primary Winding

model (5000 documents), but only the document data for the first 1000 documents is known; and (2) the contents of the file will not be static but will change due to updating. Therefore, this analysis is made for a hypothetical set of wiring patterns that simplifies the problem and yet gives results that are conservative compared with the worst conceivable actual case.

This hypothetical case can be described as follows:

(1)* A group of 120 cores adjacent to the diode end of the MIRF circuit are considered.

(2)* Half of this group (60 cores) are energized simultaneously.

(3) The 60 energized cores are considered to be lumped together and to be located six feet from the diode (open) end of the windings.

(4) 5000 secondaries** are associated with the energized cores, 2500 wires threading the cores and 2500 bypassing them.

(5) The 2500 pairs of secondaries lie contiguous to one another for a distance of six feet on the diode side of the energized cores.

Figure 23 shows this pattern schematically. All secondaries are connected to a common bus on the left of the energized cores. The capacitance for each pair of secondaries is computed from the formula for the capacitance between two round conductors,*** as follows:

$$C = \frac{3.677}{\log_{10}\left\{ D/d \left(1 + \sqrt{1 - 1/(D/d)^2} \right) \right\}} \text{ pfd per foot.}$$

---

* These conditions correspond to the actual worst case in the MIRF model--viz., the Accession Number and Superimposed Search Code sections of the Document MIRF.

** The fully expanded MIRF will have three sets of cores, two sets associated with 2000 documents and the third set associated with the remaining 1000 documents. The corresponding cores in each set will be connected in parallel and driven by the same driver. Schematically this may be represented by a single set of cores for the 5000 documents.

***See F. E. Terman, Radio Engineers Handbook, 1st ed., p. 118, Eq. (140).

For #36 wire insulated with heavy Formvar (0.006-inch-diameter) the capacitance for is 13.6 picofarads per foot. Therefore, the total capacitance for 2500 pairs of six-foot length is $2500 \times 6 \times 13.6 = 0.205 \times 10^6$ picofarads (= 0.205 microfarads). The voltage developed between the threading and bypassing groups of secondaries is 0.8 volts* for each energized core. Since the sixty energized cores are effectively in series, the capacitance must be charged to 48 volts.

Now the problem is to determine whether the capacitive current flowing can be of such magnitude as to prevent a drive circuit from supplying sufficient current to produce a standard output voltage on a secondary. To meet the design specification on transient response, the capacitance should be charged in 1-1/2 microseconds. To charge the total capacitance to 48 volts in this time would require an average current of 6.4 amperes. This current produces an MMF of 6.4 ampere turns in the direction to oppose the MMF produced by the drive current in the primary winding. The drivers are designed to have the capability of producing a 0.8-volt output pulse for ten microseconds on the secondary windings, in the absence of the capacitive current. Because the primary winding looks almost like a pure inductance to the driver, the primary current rises nearly linearly from zero to 2.1 amperes. Therefore, the driver must have the capacity for supplying 2.1 amperes to the twenty-turn primary winding, and so for producing an MMF of 42 ampere turns. During the first 1-1/2 microseconds, the MMF rises to only 6.3 ampere turns (15% of 42). It can be seen that the excess capacity of the drive circuit (42-6.3) is more than adequate to supply the current required to charge the inter-item capacitance.

(4) Analysis of Flux Leakage Problem

In an idealized case, a wire that passes outside a magnetic core would not be influenced by flux changes in the magnetic circuit. In physical circuits, however, flux is not wholly confined within a magnetic structure and a small voltage is induced in wires that pass outside, but near, the structure. When the magnetic

---

* This is the design specification for the MIRF circuit.

structure is made in two parts and has air gaps, this leakage flux problem is aggravated--especially in the vicinity of the air gaps.

In the MIRF experimental model, each item wire follows a complex path associated with many cores, threading some cores and bypassing others. During the basic MIRF operation of searching, a match on a particular item results when its item wire bypasses all cores that are energized. Since many cores may be energized, the voltage induced in the selected (i.e., match) wire by leakage flux at each core must be very small in order to assure that the cumulative voltage will be acceptably small. The design goal for the experimental model is that the maximum cumulative voltage due to leakage flux be less than 15 percent of the voltage induced in a wire that threads one energized core. Since, in the worst case, a selected wire may be subjected to leakage flux from 57 cores, the maximum voltage contribution per core is 1/57 x 0.15 x 0.7 volts, or less than two millivolts. This corresponds to a leakage flux of 1/4 of 1 percent at each core.

To achieve the design goal, two methods for reducing the leakage flux are employed:

(1) Contoured distributed primary windings

(2) Cancellation techniques.

The principal involved in the use of a contoured distributed winding is one of compensation of the magnetic potential drop by a corresponding rise in magnetic potential at the points where the drop occurs. To obtain the most effective cancellation the winding should be distributed completely around the core. However, in order to allow the windings to be wound on bobbins which can then later be slipped over the legs of the core, only two legs may be used for the distributed winding. An assembled core having the two wound bobbins is shown in Fig. 24. The winding shown has a linear spacing except in the center where two turns are closely spaced to compensate for the potential drop across the gaps. Figure 25 shows the idealized magnetic circuit spread out as though the core were opened on a plane through AA. The lower drawing shows the potential drop and the potential rise around the circuit

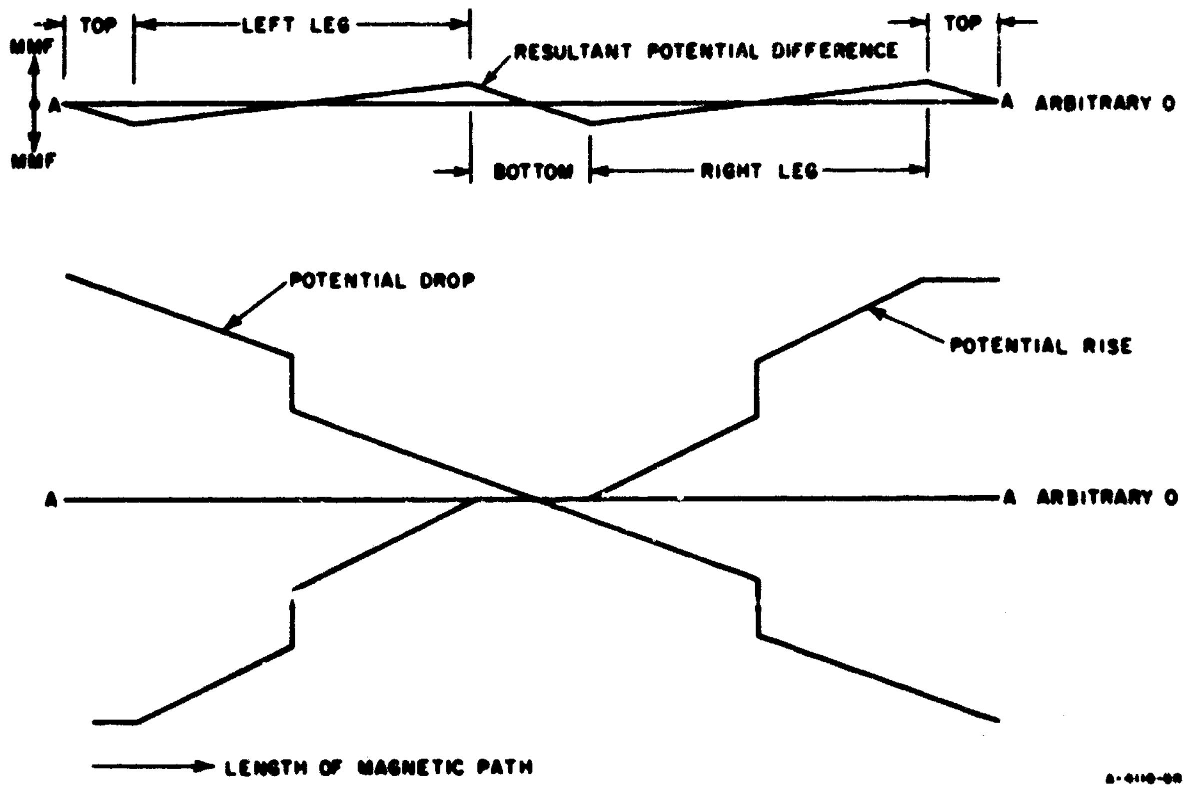


Figure 25. Magnetic Potentials in Core, Shown As If Core Were Spread Out in One Dimension

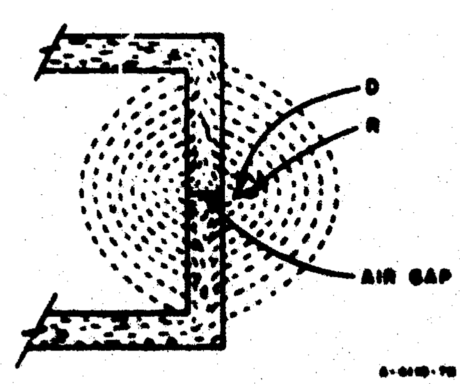


Figure 26. Detail of Leakage Flux Cancellation Scheme

with an arbitrary zero of MMF for reference. The upper drawing shows the resultant potential difference of the circuit. The leakage flux is a function of the potential difference between two points on the magnetic circuit and inversely proportional to the distance between them. It is seen then that the results of the contoured distributed winding is to greatly reduce the leakage flux by decreasing the potential difference along the whole leg length.

The effect of the noise cancellation winding may be explained by referring to Fig. 26 which shows the relation of two wires to the leakage flux paths. One wire represents an item winding and the other a cancellation winding. The item wire D, being closer to the core, is linked by a slightly greater amount of leakage flux than the return (cancellation) wire R. By connecting these two wires so that the induced voltages cancel, the net voltage will be only the difference of the leakage flux signals induced in the two wires. In a group of MIRF cores the item wire would thread and bypass cores in a unique pattern and the cancellation wire would bypass all cores. Cancellation of the induced signals would be effected by joining the two wires together at one end and taking the output signal from the other end. In practice there need not be a unique return wire associated with each item wire. One return wire may be associated with a small group of item wires, all of which are joined to the return wire at the one end of the array of magnetic cores. In the MIRF model there are about 180 item wires associated with a return wire.

E. Mechanical Design

(1) Areas of Effort

Mechanical design effort was spent in two principle areas. One is the over-all layout of equipment in the experimental model and the housing of the equipment to provide maximum accessibility to circuits. This phase of a mechanical design is well illustrated by the photographs of Figs. 2 through 6. The other and more challenging area is the design of structures for holding the U cores of the dictionary and document MIRF units. Two separate physical structures are used, one

for each MIRF. The cores are arranged in a rectangular pattern and are supported by long bobbins. These bobbins are firmly attached to a base structure and carry the primary windings for the cores.

(2) Design of the MIRF Unit Module

A MIRF module is a complete assembly of magnetic cores, primary windings for the cores, and sub modules of secondary windings with their associated diodes. One of the modules in the experimental equipment is shown in Fig. 6. The construction of a module is illustrated by the exploded view of Fig. 27. The principle parts of the assembly are the base, or coil bobbin, assembly and the item wiring trays. The coil bobbin assembly consists of a field of paper bobbins (two per magnetic core) that are cemented to a 1/8" thick phenolic board. Each bobbin carries a ten turn winding. The windings on pairs of bobbins are connected in series to form the primary winding for one of the magnetic cores. An item tray is a 1/16" thick phenolic board with a field of shallow bobbins that matches the field of coil bobbins. The bobbins on the item tray are slightly larger than the coil bobbins, permitting item trays to be stacked up on the coil bobbin assembly. 286 item wires can be accommodated by one item tray. The diodes that are connected in series with the secondary windings and form the input circuit to the discriminating amplifier are mounted on the edge of the item tray. A MIRF module is assembled by sliding up to seven item trays into position on the coil bobbin assembly. One set of U cores is then inserted into the set of coil bobbins and are held in place by a plate with a spongy silicon material pad. The other set of U cores is then dropped into position on the opposite side of the bobbin coils. Finally the top plate also with a spongy pad, is dropped into position to hold the entire assembly intact. The two sets of U cores are held together under slight pressure from the silicon pads. Throughout this design special attention was given to achieving a reliable method of disassembling and reassembling the module so that sub modules of item wiring could be changed easily.

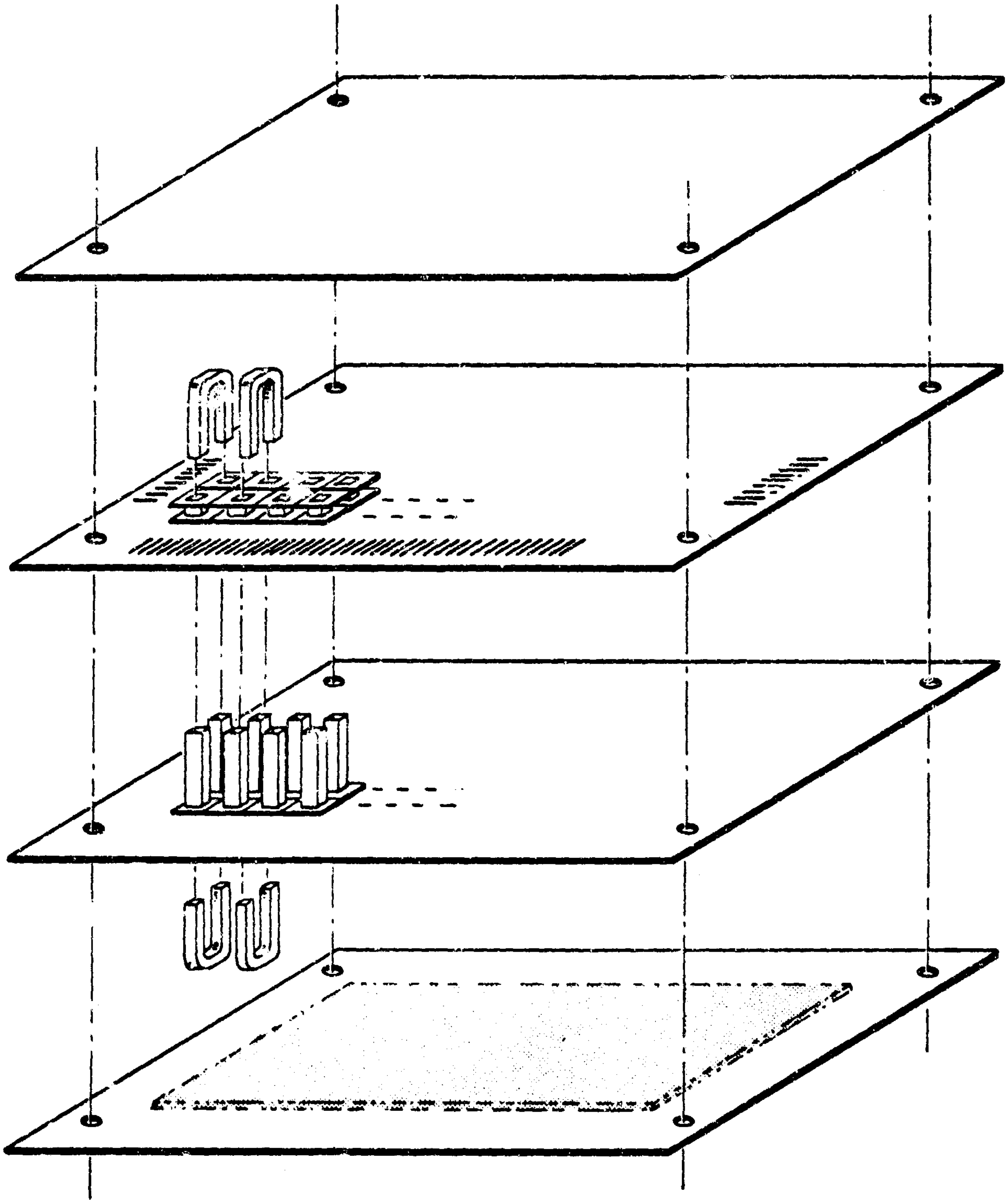


Figure 27. Exploded View of MIRF Module

Several details of the construction are illustrated by the following photographs. Fig. 28 shows the bottom side of the coil bobbin assembly partly wired. The bottom of the coil bobbins with the terminals of the primary winding can be seen inside the round clearance holes in the phenolic board. A complete item tray is shown in Fig. 29. The item wires start in the upper left corner of the trays where they are connected to a common bus bar. They pass from left to right in the first row of cores, then back and forth until they emerge in the lower left center part of the tray. The wires then run to assemblies of diodes where each wire is connected to its own individual diode. The output side of the diodes (the cathodes) are connected together and wired to a small connector which is seen in the lower lefthand portion of the tray. Even though each tray contains detailed wiring for 286 items, only two wires run from the tray to the external discriminating amplifier. Figure 29 also shows a pair of primary coil bobbins with the two U cores inserted. Several item tray bobbins that would carry the secondary windings are also shown. A closeup of a MIRF module with the top plate removed is shown in Fig. 30. The tops of one set of U cores can be seen as well as four item trays. The connectors for the output of the item trays can be seen in the lower center part of the photograph. The discriminating amplifier circuits (one for each of the 7 item trays that can be included in a module) are located on the circuit board that is mounted in front of the magnetic module.

F. Expermiental Results

(1) Equipment Checkout

The detailed checkout of the experimental model was carried on in two phases. In the first, work was done simultaneously on three major sub divisions of the control logic and on the dictionary and document MIRF units. This part of the checkout was accomplished in approximately four calendar weeks. The second phase of the checkout consisted of the integration of the four major portions that had been separately checked out and the testing of the over-all system. The

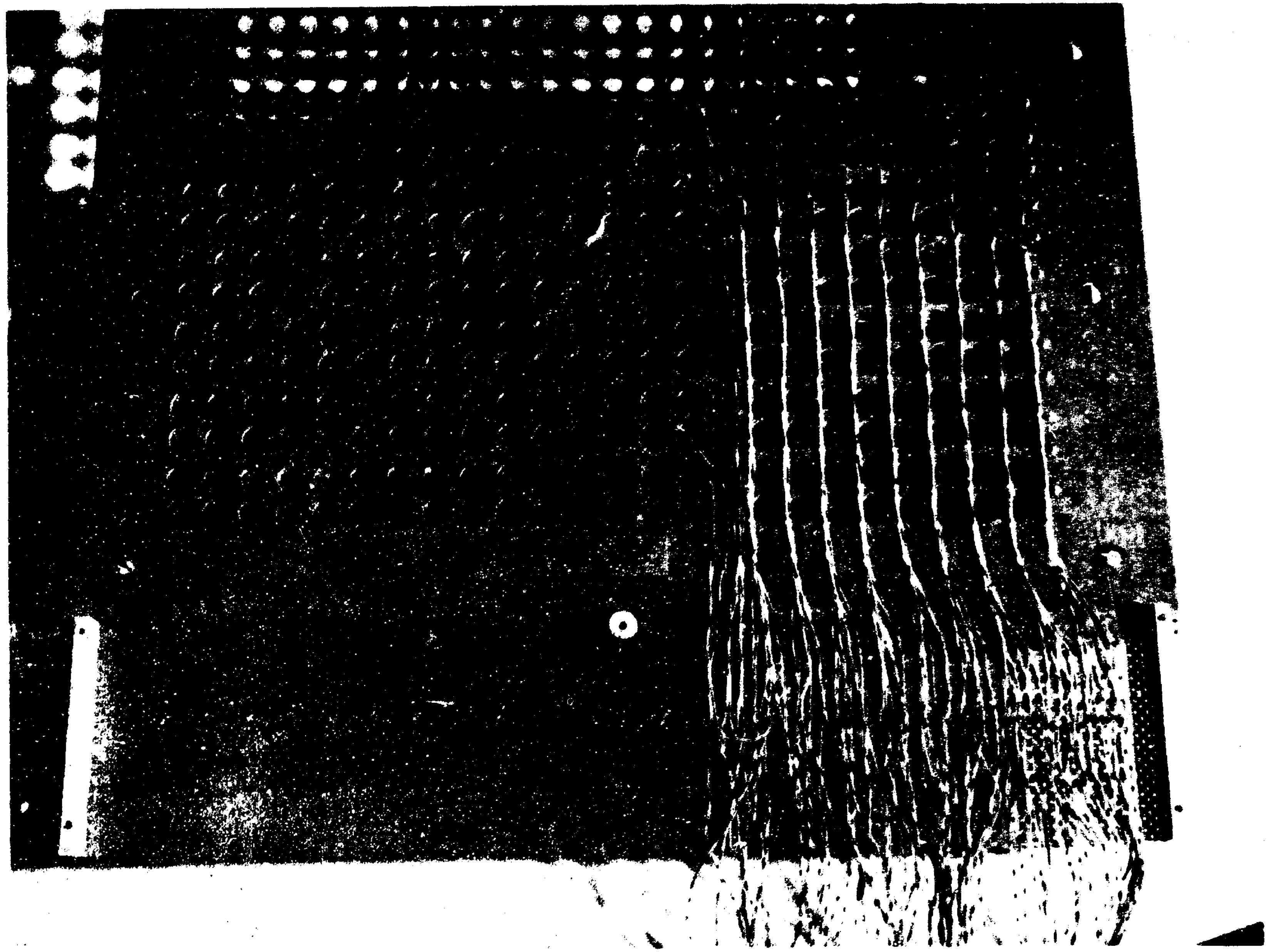


Figure 28. Bottom View of Core Bobbin Assembly (partially wired)

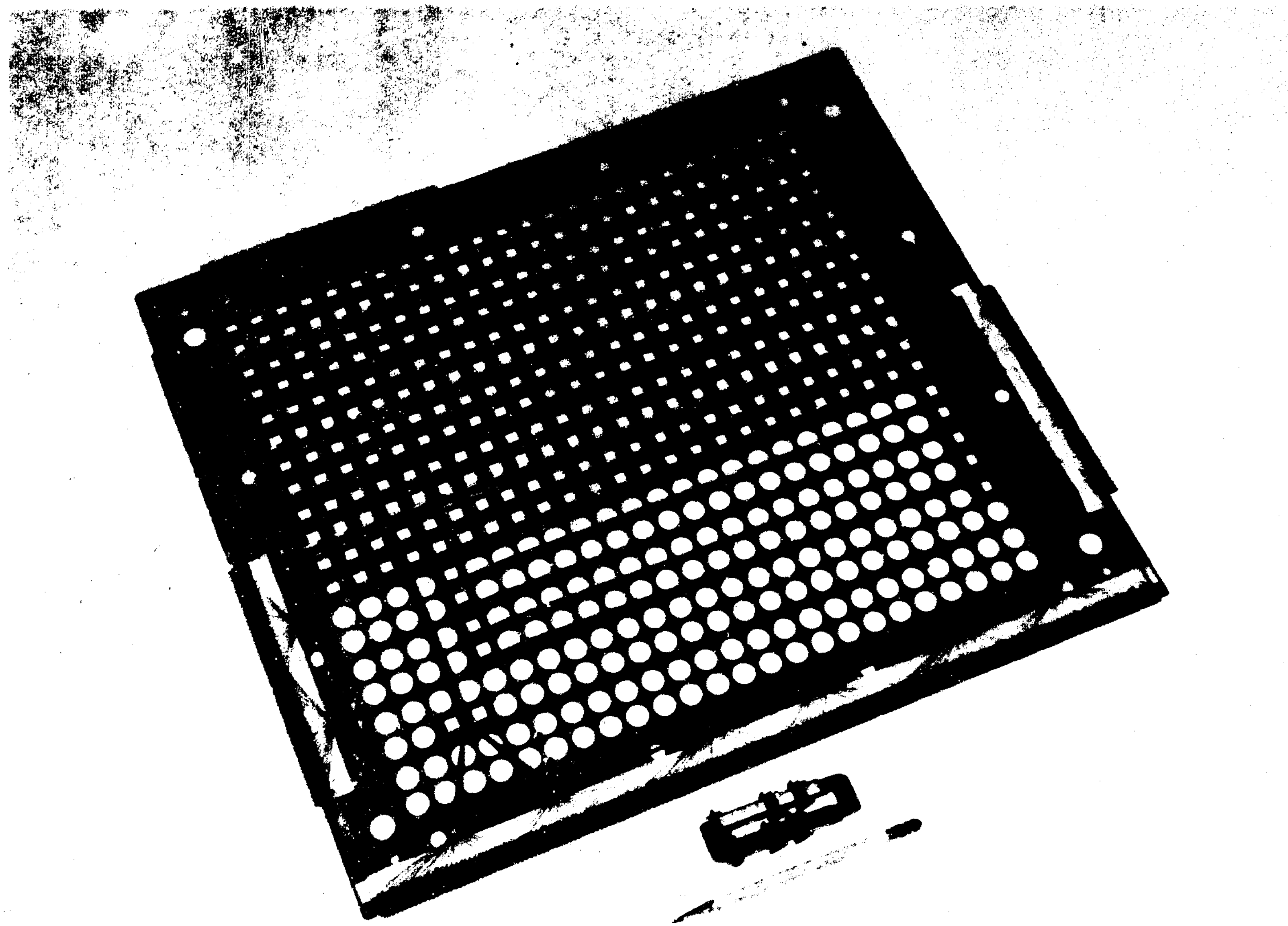


Figure 29. Completely Wired Dictionary Item Tray

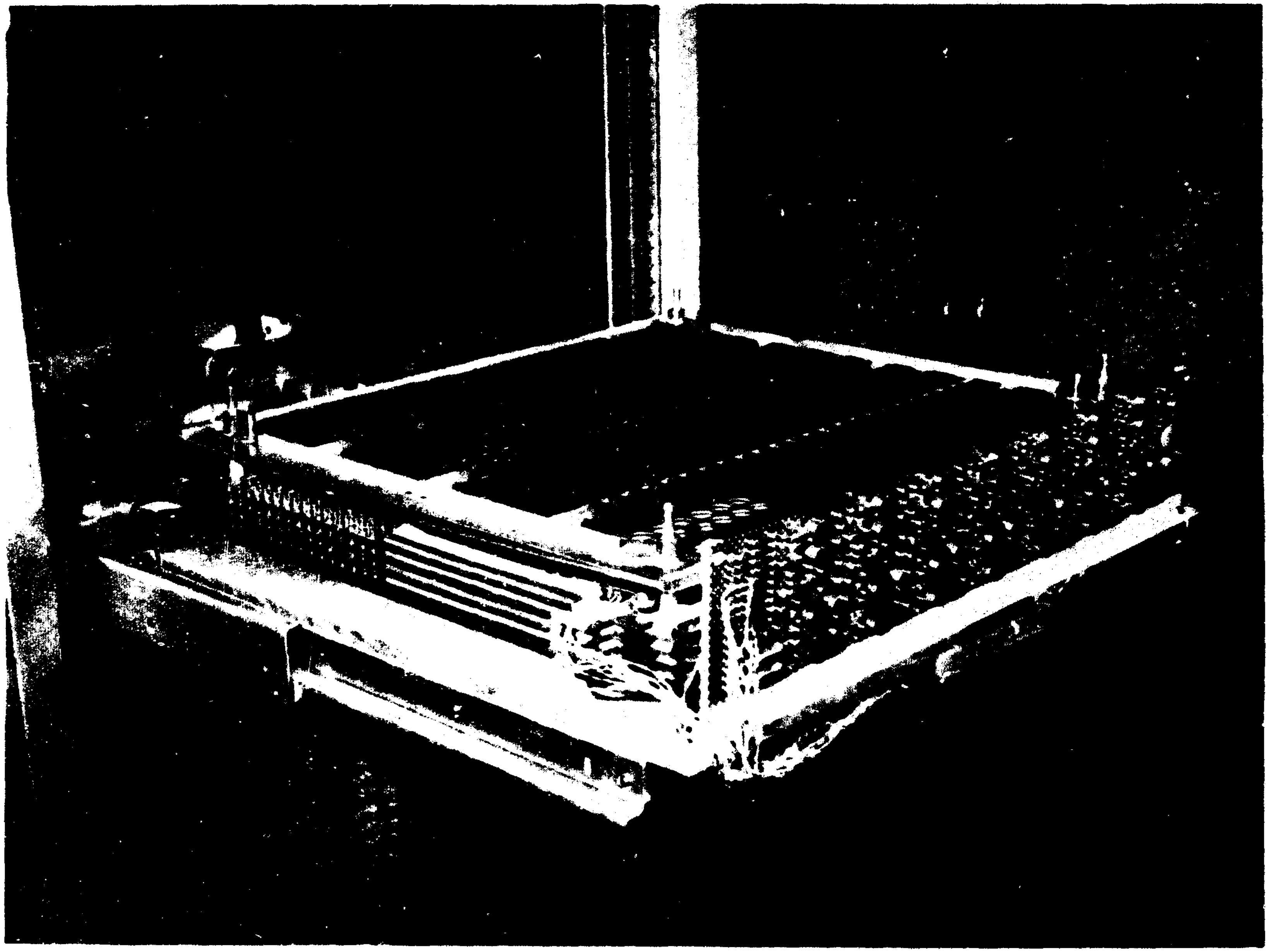


Figure 30. Close-up of MIRF Module in Equipment Cabinet of Experimental Model

second phase required approximately eight calendar weeks. The most common source of trouble in both phases of the checkout was errors in the back panel wiring in the logic and control section of the equipment. Errors in gate signal timing and incomplete logical conditions also required a large portion of the debugging time. Beside these ordinary checkout difficulties, there was only one significant source of trouble: namely, noise on the system voltage busses caused by the very large surge currents which flow during the interrogation of the MIRF units. This condition was rectified by adding large (100 microfarad) tantalum capacitors at the end of the voltage busses on the MIRF driver modules and by adding smaller (1.5 microfarad) tantalum capacitors on the Elco connectors that the MIRF driver circuit boards are plugged into.

At the end of the checkout period all logical operations designed into the equipment worked properly. A printout of the contents of the document MIRF unit was made to check the contents of the document MIRF and the translating capability of the dictionary MIRF. All of the more than 1,000 documents indexes appeared in this printout and more than 90 percent of the printouts were perfect. Most of the remaining 10 percent contained only one error in a descriptor. Some contained errors in two or more descriptors and a few (less than 5) contained so many errors that they would be considered useless. A complete check of the dictionary MIRF unit as an input device was also made and it was found that more than 98 percent of the roughly 1,000 dictionary words could be entered from the input typewriter. Errors in wiring of the item trays of the dictionary (misspellings, parity errors, etc.) prevented the successful entry of words from the typewriter.

(2) Examples of Responses to Search Questions

Figures 31 through 36 are reproductions of actual printouts made by the experimental equipment. The format of the typewritten record of a search in the experimental model is shown in Fig. 31. The first two lines "Stanford Research Institute Project 4110, etc." is a manually typed heading for the subsequent search. It was typed while the typewriter was effectively disconnected from the rest of

```
STANFORD RESEARCH INSTITUTE  PROJECT 411Ø

MULTIPLE INSTANTANEOUS RESPONSE FILE

CODING,COMPUTERS,DIGITAL.
Ø156 *CODING,DIGITAL COMPUTERS,DATA PROCESSING SYSTEMS,LANGUAGE,
Ø2Ø1 RADAR PULSES,RADAR SIGNALS,*CODING,DIGITAL COMPUTERS,
Ø42Ø DESIGN,DIGITAL COMPUTERS,*LANGUAGE,CODING,ANALYSIS,
Ø54Ø DIGITAL COMPUTERS,ERRORS,LANGUAGE,CODING,MATRIX ALGEBRA,
Ø727 *LANGUAGE,*CODING,*HANDBOOKS,DATA PROCESSING SYSTEMS,DIGITAL COMPUTE
Ø732 DIGITAL COMPUTERS,CODING,TELETYPE SYSTEMS,DISPLAY SYSTEMS,MAPS,
Ø824 DATA PROCESSING SYSTEMS,DIGITAL COMPUTERS,OPERATIONS RESEARCH,CODING,
```

Figure 31. Format of Typewritten Record of a Search

the equipment. The search question consists of three words, namely "coding," "computers," "digital." This line was also typed manually. The rest of the printout is the machine's response to the search question. Seven documents responded. For each one, a four digit accession number and the English words that describe the document are printed on a single line. The asterisk prefix on some words has been copied from the ASTIA abstract. It will be observed that the three search words appear in every responding set of indexes. It should be especially noted that the search words appear in different positions and different order in the different responding documents. This independence of order of the search words and the position of the corresponding descriptors in the document indexes is an important result of the superimposed coding of the search field.

The capability of the MIRF experimental model to reduce the number of responding documents as the search question is made more specific is illustrated by Fig. 32. First a search was made with a two word search question "infrared," "radiation." Thirteen documents responded. The word "atmosphere" was then added to the original words of the search question and a second search was made. This time only three documents responded. Finally the word "sun" was added to the previous descriptors and a search was made. This time a single document responded to the search question. The principal illustrated here is that both the number of responses and the detailed contents of the responses to a general question can easily be found. Scanning the output of a general question reveals immediately descriptive words that can be added to the question to restrict the responses to the area of direct interest. Of course, more than one word could be added to the original set of words at a time.

Figure 33 illustrates the capability of the experimental model to handle synonomous input descriptors. In the first example the two words, "cerebrum" and "physiology" are chosen for the search question. In the responding document it will be observed that the word "cerebrum" does not appear but that the word "brain" does. So far as the machine is concerned, "cerebrum" and "brain" are identical

```
RADIATION, INFRARED.
Ø218 *GERMANIUM,THERMAL RADIATION,INFRARED DETECTORS,THEORY,ZINC,
Ø222 *SOLIDS,ORGANIC SOLVENTS,SOLUTIONS,INFRARED RADIATION,
Ø47Ø INFRARED RADIATION,QUANTUM MECHANICS,INTENSITY,THEORY,
Ø487 INFRARED RADIATION,EARTH,TABLES,AIR MASS ANALYSIS,
Ø5Ø3 REFRACTORY MATERIALS,INFRARED RADIATION,BLACKBODY RADIATION,SOLAR FURNACES,
Ø645 INFRARED RADIATION,SOLAR SPECTRUM,HIGH ALTITUDE,ATMOSPHERE,SUN,
Ø662 INFRARED LAMPS,SOURCES,INFRARED RADIATION,TARGETS,AERIAL TARGETS,
Ø855 WATER VAPOR,*ABSORPTION,ATMOSPHERE,*OXYGEN,INFRARED RADIATION,
Ø857 *CRYSTALS,INFRARED RADIATION,INFRARED EQUIPMENT,MIRRORS,FREQUENCY,OPTICS,
Ø91Ø *ATMOSPHERE,*GASES,INFRARED RADIATION,*ABSORPTION,TABLES,
Ø915 AEROSOLS,SCATTERING,INFRARED RADIATION,LIGHT,REFRACTIVE INDEX,PARTICLES,
Ø931 MICROWAVE AMPLIFIERS,RADIO ASTRONOMY,INFRARED RADIATION,MOLECULAR BEAMS,
Ø949 INFRARED RESEARCH,INFRARED RADIATION,SULFIDES,CADMIUM,

RADIATION,INFRARED,ATMOSPHERE.
Ø645 INFRARED RADIATION,SOLAR SPECTRUM,HIGH ALTITUDE,ATMOSPHERE,SUN,
Ø855 WATER VAPOR,*ABSORPTION,ATMOSPHERE,*OXYGEN,INFRARED RADIATION,
Ø91Ø *ATMOSPHERE,*GASES,INFRARED RADIATION,*ABSORPTION,TABLES,

RADIATION,INFRARED,ATMOSPHERE,SUN.
Ø645 INFRARED RADIATION,SOLAR SPECTRUM,HIGH ALTITUDE,ATMOSPHERE,SUN,
```

Figure 32. Example of Reducing the Number of Responses by Increasing Specificity of Search Question

```
CEREBRUM,PHYSIOLOGY.
[illegible] *EMOTIONS,BEHAVIOR,DIAGNOSIS,PHYSIOLOGY,REACTION,BRAIN,PATHOLOGY,STRESS,

BRAIN,PHYSIOLOGY.
Ø418 *EMOTIONS,BEHAVIOR,DIAGNOSIS,PHYSIOLOGY,REACTION,BRAIN,P[illegible]STRESS,


PLASTISOLS,MATERIALS,INSULATING.
Ø578 PULSE CABLES,INSULATING MATERIALS,SILICONES,PLASTICS,POLYMERS,

PLASTICS,MATERIALS,INSULATING.
Ø578 PULSE CABLES,INSULATING MATERIALS,SILICONES,PLASTICS,POLYMERS,


TYPE,READING.
Ø7Ø6 PRINTING,READING MACHINES,*READING,ERRORS,ATTENTION,

PRINTING,READING.
Ø7Ø6 PRINTING,READING MACHINES,*READING,ERRORS,ATTENTION,


THEOLOGY,SOCIOLOGY.
Ø878 ECONOMIC CONDITIONS,*ALASKA,*ESKIMOS,SOCIOLOGY,RELIGION,

RELIGION,SOCIOLOGY.
Ø878 ECONOMIC CONDITIONS,*ALASKA,*ESKIMOS,SOCIOLOGY,RELIGION,
```

Figure 33. Examples of Synonym Substitution

descriptrors. To verify the synonomous character of the two words, the search question is asked again with the words "brain,""physiology." It will be observed that exactly the same document responds. Four other examples are given in Fig. 33. In each case the synonym is used in the first search question. The synonomous descriptor appears in the responding document index and in the second search question.

Figure 34 illustrates the capability of the machine to make a special search in which one of the original descriptors is replaced by its see-also reference. In the first example the original search question contained the words, "membranes," "thin," "polymers." The blank line immediately below the search question indicates that there was no response to this three word question. The three words that appear below the original question is the heading for the machine initiated search. Here the word, "films," has been substituted as a see-also reference for "membranes." (The ampersand symbols indicate that five possible positions in the original search question were not used.) One document responds to the new search question. The set of descriptors shows that this is a document that is pertinent and one that would have been missed if the see-also substitution had not been made. In the second example the three words, "klystrons," "electron," and "tubes," are used as the search question. One document responds to the manually inserted question. The machine then automatically substituted the word "amplifiers" for "klystrons," typed out the new search question, "amplifiers," "electron," "tubes," and then intiated a new search. Six documents responded and three of them--268, 290, and 308--are relevant to the original question. Numbers 306 and 334 probably would not be of interest and No. 455 responded to the manually inserted question. These examples illustrate that the capability of the machine to modify the search question and to initiate a new search is apowerful feature.

The capability of the machine to modify the original search question by taking information from responding documents as well as from the input question is illustrated in Fig. 35. Here the original search question was "attitude," "learning." There was no response to these two words and the machine indicated this

```
MEMBRANES,THIN,POLYMERS.

FILMS,THIN,POLYMERS,&,&,&,&,&,
ØØ14 RESONANCE,POLYMERS,WATER,THIN FILMS,OPTICAL ANALYSIS,


KLYSTRONS,ELECTRON,TUBES.
Ø455 *KLYSTRONS,ELECTRON TUBES,TESTS,MICROWAVE AMPLIFIERS,DESIGN,

AMPLIFIERS,ELECTRON,TUBES,&,&,&,&,&,
Ø268 TRAVELING WAVE TUBES,ELECTRON TUBES,MICROWAVE AMPLIFIERS,AMPLIFIERS,
Ø29Ø TRAVELING WAVE TUBES,SPACE CHARGES,*AMPLIFIERS,ELECTRON TUBES,
Ø3Ø6 ELECTRON TUBES,ELECTRONIC CIRCUITS,VACUUM TUBE AMPLIFIERS,AMPLIFIERS,
Ø3Ø8 AMPLIFIERS,ELECTRON TUBES,ELECTRON GUNS,ELECTRON BEAMS,HELIXES,
Ø334 THIN FILMS,ELECTRON TUBES,OPTICAL ANALYSIS,DIODES,TRIODES,
Ø455 *KLYSTRONS,ELECTRON TUBES,TESTS,MICROWAVE AMPLIFIERS,DESIGN,
```

Figure 34. Example of "See Also" Special Search

```
ATTITUDE,LEARNING.

PSYCHOLOGY,LEARNING,&,&,&,&,&,&,
Ø515 *LEARNING,AUTOMATION,PSYCHOLOGY,BEHAVIOR,EDUCATION,MEMORY,THEORY,READING.
Ø961 *BEHAVIOR,GROUP DYNAMICS,PRODUCTION,SOCIOLOGY,PSYCHOLOGY,LEADERSHIP,REASONING,

*BEHAVIOR,LEARNING,&,
ØØ89 *LEARNING,ECONOMICS,THEORY,REACTION,SAMPLING,*BEHAVIOR,TEST &,
Ø5Ø5 *LEARNING,VERBAL BEHAVIOR,REACTION,TEST &,TRAINING,
Ø5Ø6 PRIMATES,AUDITORY ACUITY,INHIBITION,DEAFNESS,PRODUCTION,*BEHAVIOR,*LEARNING,
Ø51Ø *CRUSTACEA,*BEHAVIOR,*LEARNING,TEST &,ARTHROPODS,
Ø512 *BRAIN,ELECTRICAL PROPERTIES,TRAINING,*LEARNING,TEST &,*BEHAVIOR,
Ø515 *LEARNING,AUTOMATION,PSYCHOLOGY,BEHAVIOR,EDUCATION,MEMORY,THEORY,READING,
Ø82Ø *LANGUAGE,*LEARNING,MEMORY,THEORY,VERBAL BEHAVIOR,
Ø821 VERBAL BEHAVIOR,*LEARNING,REACTION,TEST &,THEORY,
Ø867 *LEADERSHIP,THEORY,GROUP DYNAMICS,BEHAVIOR,REASONING,PERCEPTION,LEARNING,
Ø868 MOTOR REACTIONS,*LEARNING,PRIMATES,BEHAVIOR,THEORY,
Ø961 *BEHAVIOR,GROUP DYNAMICS,PRODUCTION,SOCIOLOGY,PSYCHOLOGY,LEADERSHIP,REASONING,
Ø969 *LANGUAGE,VERBAL BEHAVIOR,ERRORS,TESTS,LEARNING,TRAINING,*SPEECH,
```

Figure 35. Example of "See Also" and "Asterisk" Special Searches

by indexing the printout sheet. It then substituted "psychology" as the see-also reference for "attitude" and typed out the new search question which includes the words, "psychology," "learning." A new search was initiated and two documents were found. Both of these are relevant to the original search question. After the search based on "psychology" and "learning" was finished, the machine tested to see if any of the responding documents contained a word with an asterisk prefix. Document 961 contains the word "behavior." The machine then substituted "behavior" for "attitude" and initiated another search - this time based on the words, "behavior" and "learning." Twelve documents responded to this new question. All of them are pertinent in a general way to the original question and it would be easy for the searcher to select the ones of particular interest to him.

(3) False Response Performance

In the experimental MIRF equipment document searches are made using the superimposed code technique*. Because of ambiguities in the superimposed coding, accidental retrievals or "false drops" are occasionally experienced. Specifically a false drop is a response that is not related to the search question. The probability of obtaining a false drop during a search is a complex function of the detailed characteristics of the superimposed coding that is used. With a given superimposed code field length, the false drop probability is proportional to the number of descriptors used in the search question, decreasing rapidly as the number of descriptors is increased. In the experimental equipment at least two descriptors are required for usable false drop performance.

---

*See Technical Report RADC TR-61-233, "Multiple Instantaneous Response File," by Jack Goldberg and others, pp. 33-42 and 93-120

Since the false drop rate is a probability, considerable use of the equipment must be made in order to determine the false drop rate statistically. Time available during the checkout phase of the equipment did not permit a complete study of the false drop problem. However, the following generalizations can be made: First, no false responses were observed with search questions including three or more words. Second, false drops were seen with search questions of two words, but the rate of occurrence appeared to be small enough to be acceptable. Third, if only one word is used in the search question, many false responses are obtained. Figure 36 illustrates the kind of responses one can expect if a single word is used in the search question. The search word is "apes." The first four documents that respond have nothing at all to do with"apes." The other document indexes that are printed out are true responses (it will be noticed that the word "primates" appear in place of "apes." This is because "apes" is a synonym.) The machine further made a see-also special search on the word "man." Here will be observed that the first response is a false drop but that the second one is a true response.

(4) Indications of Errors in the Printed out Responses

The equipment has been designed to provide a clear indication of errors in the typewritten record of a search. One type of error indication is illustrated in Fig. 36. It will be observed that there are no index terms following the number 809. The absence of index terms indicates that a parity error was found when the coded dorm of the accession number 809 was tested.

The indication for an error in a descriptor is illustrated in Fig. 35. In documents number 89, 505, 510, 512 and 821 the word "test" is followed by an ampersand. The presence of the ampersand indicates that the code of the word generated after "test" did not match any code in the system dictionary. (For this particular case it is known that the word represented by the ampersand is "methods." Further it is known that the trouble is in the wiring of the word "methods" in the dictionary MIRF unit.)

```
APES,
Ø196 GROUPS,OPERATORS,FUNCTIONAL ANALYSIS,COMPLEX NUMBERS,CONVEX SETS,
Ø4Ø8 OPTICS,ELECTRON BEAMS,WAVE ANALYSIS,PROJECTIVE GEOMETRY,SWEDEN,
Ø457 COMPLEX VARIABLES,CONFORMAL MAPPING,FUNCTIONAL ANALYSIS,MEASURE THEORY,
Ø499 PRESSURE,LOADING,*STRESSES,ANALYSIS,*ELASTICITY,THICKNESS,*SURFACES,GRAPHITE,
Ø5Ø6 PRIMATES,AUDITORY ACUITY,INHIBITION,DEAFNESS,PRODUCTION,*BEHAVIOR,*LEARNING,
Ø711 *BEHAVIOR,PHYSIOLOGY,INTESTINE,REFLEX,PRIMATES,DIGESTIVE SYSTEM,
Ø8Ø9
Ø868 MOTOR REACTIONS,*LEARNING,PRIMATES,BEHAVIOR,THEORY,

MAN,&,&,&,&,&,&,&,
Ø661 THIN FILMS,*FERRITES,OXIDATION,METAL FILMS,LATTICES,SPINELS,
Ø993 *COMPUTERS,*MAN,DATA PROCESSING SYSTEMS,MEMORY,LANGUAGE,
```

Figure 36. Example of Response to a Single Word Search Question

4. Conclusions and Recommendations

A. Conclusions

In general it can be concluded that all the specifications set down for the experimental Multiple Instantaneous Response File are technically feasible. Interrogation of the magnetic storage units (MIRF's) and over-all control of the system can be accomplished with reliable circuits of modest complexity. Easy communication between a human operator and the machine has been demonstrated. The machine's response to a search question is essentially instantaneous in terms of human reaction time and the information content of the response is sufficient to allow the operator to modify his question and go directly to the document indexes of special interest. It can be concluded that certain automatic features such as the handling of synonomous input descriptors and the machine modification of the original search question can be achieved without undue complexity.

Several preliminary conclusions can be drawn from the machine performance observed during the check-out of the experimental model. It appears that the automatic substitution of the see-also reference of an input descriptor is a useful feature; but that the modification of the original search question by taking weighted descriptors from responding documents appears to be less useful. In many cases the combination of the asterisked descriptor with the original search terms gives a question with no responses. An examination of how to select descriptors from responding documents is needed in order to make this feature more useful. The capability of the experimental MIRF equipment to accept synonomous input descriptors also appears to be an important feature. Another interesting feature, which is not included in the present model, could be designed into future equipment. This would enable the machine to retrieve document indexes in which the form of the descriptor was somewhat different from that of the input (search) descriptor. The descriptors would be required to have the same root and meaning, but different word endings would be allowed.

Positive conclusions can be reached in regard to three of the most important properties of a file searching system of this type. First, it is concluded that searching by means of a superimposed code is feasible both from the standpoint of the circuits required and the false response performance that is obtained. Second, it is concluded that storage of the document index information in wiring associated with arrays of cores that are physically separable is feasible. Experience with the experimental model shows that the arrays of cores can be separated, submodules of wired information can be changed, and the core arrays reassembled in a reasonably short time. More work on the mechanical design of the magnetic modules is needed, however, to permit easier and faster changing of the stored information. Third, it is concluded that a basic system building block has been established. The experimental model as delivered to the sponsor demonstrates that good performance can be obtained with a file of more than 1,000 document indexes. Experience with the experimental model indicates that expansion to five or six thousand document indexes can be achieved. It appears that with the present design the system building block should contain about 5,000 document indexes. It also appears that as many as ten such building blocks could be combined in a system whose over-all control is little more complex than that for a single building block. Therefore it is concluded that files of the order of 50,000 indexes could be built with no major changes in the basic concepts or circuits used in the experimental model.

B. Recommendations

A program should be initiated for applying the principles demonstrated in the experimental model to a substantially larger system. Special attention should be given to the method of realizing information storage in the form of wires associated with the magnetic cores. The method selected should lead itself to automation so that the complete process of preparing stored information can be machine controlled.

A study of the further application of the Multiple Instantaneous Response File concept should be initiated. In the field of document retrieval, the effect of removing limitations on word length and the number and nature of the descriptors used in document indexes could be investigated. The use of phrases of two or more words as search entities might also be examined. The application of the MIRF principles to code and language translation and other search type operations that require rapid feedback should be studied. More generalized search problems, such as pattern recognition, should be included. Applications that make use of the inherent speed of the search equipment should be investigated. (In the experimental model, the typewriter is by far the slowest part of the system). For example, the document information storage and the search facilities of the equipment could be shared by multiple user consoles. By time multiplexing techniques, many users could be given effectively private use of the machine. Applications in which the human operator is not a key figure should also be examined. The internal speed of the equipment makes feasible the use of digital computers or other computer-like machines as input-output devices.

New developments in superimposed coding should be investigated as a means of improving the efficiency of the searching operation. Recent work has shown that it is possible to design superimposed codes which can be decomposed to give the unique set of components of the superposition. Besides being uniquely decipherable, such superimposed codes also offer the possibility of retrievals with no false responses. With the new codes it may be possible to retain the advantages of superimposed coding (for example, freedom from the field indeterminacy problem) without suffering from the ordinary disadvantages of superimposed coding (for example, a finite false response probability). A simpler over-all design of the system may also be possible using the newer superimposed codes.

APPENDIX I

OPERATING INSTRUCTIONS FOR THE AN/GSQ - 81 DOCUMENT DATA INDEXING SET

A. Machine Turn-on

(1) AC Power Turn-on. AC power is applied to the machine by throwing the AC power switch to ON. This switch is located on the table level control surface immediately at the left of the input/output typewriter. After the AC power has been turn on, an automatic sequence turns on the DC voltages in the machine in the proper order. After about 10 seconds the light associated with the AC power switch will come on to indicate that all DC voltages have reached their operating levels.

(2) Typewriter Turn-on. The typewriter should be turned on by throwing the OFF/ON switch which is located in the lower right portion of the keyboard surface to ON.

(3) Master Clearing. After the AC power indicator has come on, the master clear button located immediately to the right of the AC power switch should be depressed. Operation of this switch sets all control flip-flops in the machine to their initial states and turns on the system synchronizing clock.

B. Typing a Heading

After turning on the AC power and the typewriter and initial clearing, the typewriter is ready for use. At this time the typewriter output is not connected to the rest of the system, and the typewriter may be used in the ordinary way. Information such as the project number, the date, the name of the searcher, etc. may be typed out as a heading. All machine functions may be used, including back-space, shift, carriage return, indexing, etc. The heading may be as long as desired. At the end of the heading the typewriter should be carriage returned.

C. Entering the Search Question

After typing of the heading has been completed, the output of the typewriter is connected to the internal logic of the system by pressing the start data input

switch. A green light immediately above this switch will come on to indicate that the machine is ready to accept search question data. A search question consists of a number of English words which describe the content of the document of interest. These English words are typed one after another with a punctuation mark after each one. Normally words are separated by commas and the last word is followed by a period. If the search question includes a two-word phrase, a space is used following the first word of the phrase. At least two and at most eight words may be used in a search question.

The logic of the machine automatically checks the input words to make sure that they are included in the vocabulary of the system. If a word that is typed in is not in the vocabulary or if it is misspelled, the machine will indicate that the word is not a valid descriptor by lighting a light on the display panel. At the same time the typewriter keyboard is locked. To clear the effect of an invalid descriptor, the unlock keyboard switch should be depressed. It should be noted that the use of this switch to unlock the keyboard affects only the word that was in error. For example, if three valid descriptors have been typed in and an error had been made in the fourth, then unlocking the keyboard would not affect in any way the three valid descriptors.

D. Starting the Search

After the words of the search question have been typed and have been checked to make sure that the set of words is complete, the search is initiated by operating the carriage return of the typewriter. From the time that the carriage return operates until the typing out of responding documents has been completed, the keyboard is locked. After the search has been started, the operation of the system is completely automatic. The first thing that the operator should observe is the number of responding documents. If there are no document indexes in the file that match the search question, the no response light will come on and the machine will stop. If there is at least one document index that matches the

search question, the machine will count the number of responses and display them on the numeric indicator. The machine will then immediately begin to type out the complete index of each responding document, starting with the one having the lowest accession number.

If the number of responding documents that is displayed on the numeric indicator is very large, the operator may desire to stop the typing out of document indexes before the entire list has been completed. The typewriter can be stopped at any time by pressing the master clear button. Usually it is most desirable to stop the typing after a complete index has been typed out and the typewriter has carriage returned.

This document data indexing set has designed into it several automatic features that provide for a machine modification of the original search question and the machine initiation of new searches. It will be observed that in some cases, the machine will type a new heading after the search based on the original input descriptors have been completed. The machine will then go ahead and search and type responding documents for the second search. As many as three machine initiated searches can take place after the original search has been completed.

The indicator light marked "locked in typing mode" normally comes on while the typewriter is typing out responses to a search question. If this light stays on after the typewriter stops typing, a lock-up in the typewriter circuit is indicated. This condition should be cleared by pressing the release button which is located directly beneath the "locked in typing mode" indicator. The typewriter must not be used until a lock up condition of this kind has been cleared. If by accident the typewriter is used, the machine may behave abnormally. For example, the typewriter may begin to index and feed paper. In this case, both the master clear and the release switches should be pressed.

E. Machine Turn-off

In order to turn off the machine both the ON/OFF switch on the typewriter and

the the AC power switch should be thrown to the off position. It is important to check the condition of the typewriter ON/OFF switch to make sure that it is off because the typewriter power is supplied directly and not through the control of the AC power for the rest of the system.

APPENDIX II

LOGICAL DESIGN OF THE AN/GSQ - 81 DOCUMENT DATA INDEXING SET

A. Entering the Search Question

The circuits used in entering a search question into the MIRF system include an electric typewriter, an input/output register, and an alphabetic descriptor register. The function of these circuits is to store an English word that is typed in as part of the search question in the alphabetic descriptor register in binary coded form. As an example, consider how the word "circuit" is entered into the register. When the first letter is typed, a six-bit code is transferred to the input/output register. The contents of the register are tested to see if the code is that of an alphabetic character. Because it is, the 6-bit code is converted to a 5-bit code which is then gated to right-most portion of the alphabetic descriptor register. The code of the second letter is transferred to the input/output register, tested, and converted to a 5-bit code. After the contents of the alphabetic descriptor register are shifted 5 places to the left the code of the second letter is gated to the register. This procedure continues until the last letter, t, has been received and stored in the alphabetic descriptor register. The next output from the typewriter is either a space or a comma. The special character detector associated with the input/output register detects the fact that this is not an alphabetic code and inhibits the gating of this code into the register. Instead of gating, a signal is given which causes the contents of the alphabetic descriptor register to be shifted to the left until the first bit of the first alphabetic code is in the left-most position of the register. A signal is also generated at this time to initiate a sequence which tests to find if the English word just typed in is actually contained in the system dictionary. For this example, a word which contains less than 10 letters was chosen. If the input word conta' : exactly 10 characters, the alphabetic descriptor register is completely filled by the alphabetic code. When the space or comma is detected,

the step for shifting the register would be omitted.

Another function of the special character detectors should be pointed out at this time. After all the descriptive words of an input search question have been typed, the operator causes the typewriter to carriage return. The presence of the code for carriage return is detected in the in/out register and a signal is generated to cause the beginning of the search for documents responding to the search question.

B. Generating the Search Code

The first operation in generating the search code is testing the validity of the input descriptor. The contents of the alphabetic descriptor register are gated to the dictionary MIRF and the output of the discriminating amplifier associated with the dictionary MIRF is examined. If a match indication is found, a new sequence is initiated. If a mismatch is found, a control flip-flop is set, an invalid descriptor light is turned on and the typewriter keyboard is locked. In this case the keyboard must be unlocked before a new descriptor can be entered.

If the input descriptor is valid, a new sequence is begun which uses the alphabetic descriptor register, the serial number register, and the serial number counter. The purpose of this sequence is to generate in the serial number register the 13-bit binary serial number of the descriptor whose alphabetic code is stored in the alphabetic descriptor register. This is done by a sequence which is similar to that used in determining whether or not the input descriptor was valid. First the parity bit of the serial number is tested. In this test the value of the parity bit is assumed to be 1. If the result of the test is true, then the parity bit actually is 1. However, if the test is false, then the parity bit was 0. At the beginning of the sequence, the serial number register is cleared to all one's and the serial number counter is set so that the output of the decoder that corresponds to the parity bit is energized. Then the alphabetic descriptor register and the serial number decoder are gated to the dictionary MIRF. The output of the dictionary match detector is examined and if a mismatch is indicated,

the left-most bit of the serial number register is changed to a zero. If a match is indicated, no change is made. Then the serial number register is shifted one place to the right. At the end of 13 such cycles the serial number register will hold the 13-bit number of the input descriptor. The parity of the number in the serial number register is checked and if it is correct, the sequence for generating the search code is started. If the parity is incorrect, a control flip-flop is set, the keyboard is locked and a parity error light is turned on.

The search code of an input descriptor consists of 5 one's uniformly distributed in a field of 80 bits. The search code is generated from the 13-bit serial number of a descriptor. Actually the parity bit is not used and the remaining 12 bits are broken into three 4-bit sections. First the right-most four bits in the serial number register, not counting the parity bit, are gated to the search code generator. The four bit number is decoded to one out of sixteen leads energized and the decoder output is gated to the right-most 16 positions of the search code accumulator. Next, the serial number register is shifted four places to the right, again four bits are gated to the search code generator. After the search code accumulator has been shifted 16 places to the left, the decoded output of the search code generator is gated to the accumulator. The serial number register is again shifted to the right and the third four bit portion of the serial number is used to get the third portion of the search code. The fourth and fifth portion of the search code are obtained by performing certain logical operations on portions of the serial number. At the end of this sequence, the search code of the descriptor which is stored in the alphabetic descriptor register is stored in its proper position in the search code accumulator. The same procedure is used for generating and transferring the search code of the next input descriptor to the search code accumulator. The second and subsequent search codes are superimposed upon the first one stored in the search code

accumulator, thus generating a superimposed search code for the input question.

C. Starting the Document Search

After all words of an input question have been typed, the operator causes the typewriter to carriage return. This action is interpreted as the signal for beginning the actual search. First a test is made to see if any document in the file includes the search question. This is done by gating the contents of the search code accumulator to the document MIRF and observing the output of the document match detector. A match output indicates that one or more documents have responded to the search question. In this case a sequence is started for generating the unique accession numbers of the responding documents. If the match detector output indicates a mismatch, then the search procedure is terminated and a light is turned on to indicate that there was no response to the search question

D. Generating a Unique Document Accession Number

The procedure for generating a unique document accession number* is similar to that used in generating the serial number of an input descriptor. However, the generation of an accession number requires a two-phase operation, one phase being called a Mode-A search, and the other a Mode-B search.

(1) Mode-A

At the start of any Mode-A sequence there will be a continuous string of X (don't care) symbols in the accession number register extending from the least significant digit to some higher order digit. For example, the number d_5d_4XXXX, represents the range of numbers from $d_5d_4$0000 to $d_5d_4$1111 where d_5 and and d_4 were obtained by a previous Mode-B search. On the first test of a search, all digits will be X. Mode-A proceeds by setting the X digits to zero , one at a time, starting from the most-significant X digit and testing the file (including the search code accumulator). If the file response is positive, the trial zero is preserved in the next pattern; if it is negative, the trial zero is changed to one, e.g. if $d_5d_4$0XXX fails, the next test pattern is $d_5d_4$10XX. When all X's

---

*See E. H. Frei and J. Goldberg, "A Method of Resolving Multiple Responses in a Parallel Search File", IRE Trans. on Electronic Computers, Vol. EC-10, pp. 718-722, December, 1961.

have been removed, by shifting the inhibit number register to the right one digit at a time, the resulting number is that of the lowest-numbered responding item in the given number range. Subsequent testing proceeds in Mode-B.

(2) Mode-B

Mode-B starts with a complete number which contains no X symbols, i.e. the inhibit number register is completely reset. In successive steps, it establishes continually lengthening strings of X symbols, starting with the least-significant digit and extending to some higher order digit. Each string is headed by a one symbol. On the first test of a B sequence, if the least-significant digit is a zero, it is changed to a one, and the resultant pattern is tested. This number may be accepted as a new responding item. Whether or not it is accepted, subsequent testing proceeds in the B Mode. The next test pattern is established by changing the least-significant zero digit to one, and all lower digits to X. For example, 101001 is followed by 10101X, 0011XX is followed by 01XXXX, etc. Instances where a digit is already a zero do not require a test of the file.

If a new B pattern is accepted, a range of numbers containing one or more new responding items has been found, and the testing changes to Mode-A. If no new B pattern is accepted, i.e. if ultimately 1XXXXX is rejected, the search is ended.

E. Generating and Typing Data from the Responding Documents

After the accession number of a particular document has been generated, the accession number and the English word descriptors of that document are printed out on hard copy. The accession number is handled by gating the four left-most positions of the accession number register (which contain the BCD code of one digit) to the input/output register. A code conversion is performed to change the 4-bit code into the 8-bit code required as a typewriter input and the digit is typed. The accession number register is shifted four places to the left and the above procedure is repeated to get the second digit. This is done until all

four digits of the accession number have been printed. Next, the serial numbers of the descriptors of the document are generated by interrogating the document MIRF. The word selector is set to the position of the document MIRF which corresponds to the first descriptor to be printed out. The serial number counter is set so that the decoded output lead that corresponds to the parity bit of the serial number is energized. Then the accession number register and the decoded output of the serial number counter are gated to the document MIRF. The output of the document match detector is gated to the left-most position of the serial number register. The serial number register is shifted one place to the right, and the serial number counter is advanced one. Then the accession number register and the decoded counter are again gated to the MIRF. This procedure continues for 13 cycles and at the end of this time the serial number of the first descriptor is stored in the serial number register. The next step is to translate the serial number of the English word into alphabetic code that can be used to operate the typewriter. This is done by gating the entire contents of the serial number register to the dictionary MIRF along with one bit of the alphabetic descriptor register. At each gating to the MIRF the dictionary match detector is gated to the input/output register and after five cycles the five-bit code of one alphabetic character is stored in that register. After the character has been printed the generation of the next alphabetic letter is started. This continues until all letters of the first descriptor have been generated and printed and then the word selector is set to the second word. The 13 bit serial number of the second descriptor is then generated and following this the alphabetic codes of the English letters of that descriptor are generated and printed. This procedure continues until all of the descriptors associated with a particular document have been printed out. Then the test is made to see if there are other responding documents. If so, the accession number of the next responding document is generated. If not, the special machine initiated searches are started.

F. See Also Special Search

In the see also special search, a new search question is generated by replacing one of the descriptors of the original search question by its see also reference. In order to accomplish this, a means for storing all of the input descriptors must be provided. Also, the serial number of the see also reference must be generated and stored. In this indexing set, these functions are accomplished as follows:

After the test has been made on the input descriptor and it has been found to be valid, a test is made to see if there is a see also reference associated with that descriptor. This is done by gating the contents of the alphabetic descriptor register to the MIRF at the same time that a see also test bit is gated to the MIRF. The output of the dictionary match detector is examined to determine the presence of a see also reference. If there is a reference, the serial number of the see also reference is generated bit by bit as explained before and is stored in the serial number register. If its parity is correct, the 13-bit number is transferred from the serial number register to a slot in a core memory register. Then the serial number register is cleared and the serial number of the manually inserted descriptor is developed. If its parity is correct it is transferred to a different position in the core memory. Then the search code of the manually inserted descriptor is generated as described in a previous paragraph. Actually only one see also reference serial number is stored in the core memory, namely the first one that is detected. When a see also reference is found, a control flip-flop is set to record this fact.

When the search based on the manually inserted descriptors has been completed, a test is made to see if the see also reference flip-flop has been set. If so, the search accumulator is cleared and a sequence is initiated to generate the new search question. To do this the magnetic core memory is examined. If there is a see also reference serial number stored in the first slot of the memory, it is transferred to the serial number register. Then the search code of this serial

number is generated and transferred to the search code accumulator. If the first slot in the core memory does not contain a see also reference, the serial number of the first manually inserted descriptor is transferred from the core memory to the serial number register and its search code is generated. Each memory slot is examined in this way and either the serial number of a see also reference or of a manually inserted descriptor is transferred to a serial number register and a search code is generated. In this way a new search question is developed. When the last position of the core memory has been tested, a signal corresponding to the carriage return of the operator is developed and a search sequence with the new search question is begun.

In order to mark the beginning of the printout of a see also special search on the typewritten hard copy, a see also heading is printed. For each serial number that is transferred to the serial number register, the alphabetic codes are generated by the MIRF interrogation sequence and the alphabetic letters are typed out. All English word descriptors appear on one line. The internally generated signal which starts the see also special search also commands the typewriter to carriage return.

G. Asterisk Special Search

In the asterisk special search a new search question is generated by using a descriptor that has been obtained from one of the responding documents. This descriptor must be different from any descriptor used in the manually inserted search question and it is added to the second and third descriptors of the original search in order to get the new search question.

Each descriptor serial number stored in the document MIRF has a special bit position that is used to indicate whether the descriptor is marked by an asterisk. After the serial number of a descriptor of a responding document has been generated and stored in the serial number register, a test is made to see if the asterisk bit is a one (i.e., the descriptor is marked by an asterisk). If it is, the

contents of the serial number register and the slot of the core memory that contains the first manually inserted descriptor are fed to a comparator and are compared bit by bit. A perfect match means that the descriptor obtained from the responding document is exactly the same as the first manually inserted descriptor. If there is a match, the serial number in the serial number register is discarded so far as the special asterisk search is concerned. A mismatch during the comparison means that the descriptor from the responding document is not the same as the first manually inserted descriptor. However, it may be the same as the second, third or other of the manually inserted descriptors. Therefore the contents of the serial number register are compared with the contents of the second, third and other slots of the core memory to see if the responding descriptor is the same as any input descriptor. If no match is found during this process the descriptor is stored for future use by transferring the contents of the serial number register to a special position in the magnetic core memory. Then a control flip-flop is set to indicate that a descriptor with an asterisk has been found.

After the search based on the manually inserted descriptors and a see also special search (if any) have been completed, a test is made to see if the asterisk control flip-flop has been set. If so, the search accumulator is cleared and a sequence is initiated to generate the new search question. To do this the portion of the magnetic core memory that contains the stored serial number of the astorisk descriptor previously found is examined. The serial number is transferred from the core memory to the serial number register and the search code corresponding to this serial number is generated and transferred to the search code accumulator. Then the serial number of the first descriptor that was manually inserted is transferred from the core memory to the serial number register and its search code is generated and transferred to the search code accumulator. Likewise the serial number of the second manually inserted descriptor is handled. When the generation of the new search question is completed

a signal corresponding to the carriage return of the operator is developed and a search sequence with the new search question is begun.

As in the case of the see also special search, a special heading is printed out to indicate the beginning of the asterisk special search. For each serial number that is transferred from the core memory to the serial number register the alphabetic code is generated by the MIRF interrogation sequence and the alphabetic letters are typed out. All English word descriptors of the new search question appear on one line. The internally generated signal that starts the asterisk search also commands the typewriter to carriage return.

APPENDIX III

REDUCTION OF RAW DOCUMENT INDEX DATA TO THE FORM USED IN THE WIRING JIG

A. Introduction

The documents whose indexes are stored in the document data indexing set were selected by Rome Air Development Center personnel. The document information was furnished to Stanford Research Institute in the form of clippings from ASTIA Technical Aspect Bulletins mounted on 5 x 8 inch index cards. Each card was marked with a four digit personal number which was used as the accession number in place of the longer AD number. In the descriptor portion of the ASTIA abstract, the words that were to be used in the document index were underscored. Single and multiple word descriptors were used with the total number of words limited to 8 and the number of letters per word limited to 10. In checking the approximately 1100 cards furnished by RADC, errors, such as too many letters in a word or missing or unmarked descriptors, were found in about 10 percent of the cards. After these errors were corrected, the accession number and descriptor data were reproduced in punched-card form. Computer programs were then written to translate the alphanumeric information into the detailed binary information required for wiring the actual item trays. The output of the computer processing was a set of punched cards that were used in a punched card reader that formed the input to special wiring equipment.*

B. Procedure for Translating Document Data into Machine Readable Form

This section describes the procedures used to translate the ASTIA document information to punched cards which were suitable for machine reading.

Before the data could be transcribed, a simple form was designed for use by the key-punch operators (see Fig. III-1). This was necessary because it could not be expected that the key-punch operators could produce error-free punched cards if they were required to read directly from the marked ASTIA data.

---

* See Appendix IV.

MIRF DOCUMENT-DESCRIPTION CODING FORM

1	accession number 3–6		descriptor 11–20	link	descriptor 25–34	link	descriptor 39–48 / 53–62	link 52 / 66
	0013	1	MAPPING	1	TERRAIN		ELECTRONIC	1
							SCANNERS	
	0013	2	TARGET	1	PLOTTERS		AUTOMATIC	
							ANALYSIS	
	0014	1	RESONANCE		POLYMERS		WATER	
							THIN	1
	0014	2	FILMS		OPTICAL	1	ANALYSIS	
	0015	1	PLASMA	1	PHYSICS		MAGNETIC	1
							FIELDS	
	0015	2	WAVE	1	ANALYSIS			
	0016	1	GLOW	1	DISCHARGES		ELECTRODES	
							ELECTRIC	1
	0016	2	ARCS		STABILITY		GASES	
							METALS	
	0017	1	OPTICS	*	FOCUSING	*	LENSES	*
	0017	2	OPTICAL	1	EQUIPMENT		ANALYSIS	
	0018	1	MAGNETIC	1	PINCH		SCIENTIFIC	1
							RESEARCH	
	0018	2	PLASMA	1	PHYSICS			

Figure III-1. Format for Coding MIRF Document Information

The use of this form required that someone manually transcribe the marked ASTIA data onto the form. This step in the process was the weakest link from the point of view of introducing errors, and thus checking procedures were used.

Since there is a maximum of eight words of ten letters each plus a four-digit serial number associated with each document, two punched cards per document are required. (A standard punched card has capacity for 80 characters.) Each of the two cards contained the document serial number and a subnumber ("1" or "2") identifying the first and second card. The first card contained the first four words of the descriptors and the second card contained the last four. Both cards were used regardless of the number of words--i.e., the second card may contain only the document number and the subnumber "2."

The procedure required that the following data be transcribed onto the form:

(1) Document serial number, once for the first card and once for the second card (the subnumber was entered on the master of the form)

(2) Up to eight words forming the document descriptors

(3) "Links"--a symbol used between adjacent words to indicate they are part of a multiple word descriptor

(4) Asterisks indicating an important descriptor.

This data was transcribed by hand and not proof-read. The forms were then sent to key punch operators who prepared punched cards. A listing (printing the contents of the cards on an IBM 407 tabulating machine) of the deck was then obtained to be used for proof-reading.

The listing was then very carefully compared against the original ASTIA data. (The forms used for key punching were no longer used.) Approximately 6 percent of the entries in the listing had some sort of error. The majority of errors were omissions of a "link" symbol or the asterisk. In addition, some words were misspelled. There were only a few key-punching errors. The correction of

these errors was marked directly on the listing, and then the listing and deck of punched cards were returned to the key punchers for correction.

After the punched cards were corrected, a new listing was made and this new listing was again compared against the original ASTIA data. Approximately one-half percent of the documents still had errors of some sort. These errors were corrected and proof-read and the deck of punched cards was then assumed to be error-free. This completed the punched cards to be used as input data by the computer to prepare wiring-aid data to wire the document MIRF.

The next step in the processing was directed toward obtaining a deck of punched cards to be used as input data by the computer to prepare wiring aid data to wire the dictionary MIRF. The major portion of this processing was done on punched card machines.

The document punched cards prepared above were read and a new card was punched for every descriptor word on the document card. The new card contained only the alphabetic word. This new deck of cards was then sorted and listed. This listing was scanned for misspelled words (five were found) and was also used to give an indication of the frequency of use of word. The deck was then processed to remove all duplicate cards. The remaining deck containing one card per word was retained for further processing.

It was desired to take this last deck of cards and assign a serial number to each card (and thus to each word). The serial number was to be a 12-bit binary number and there was to be a random assignment of the serial number to the word. To accomplish this, a short computer program was written in the ALGOL langugage for preparing a deck of punched cards with a 12-bit binary number in octal form together with a pseudo-random 5-digit decimal number. This punched card deck was then sorted on the pseudo-random number.

The punched card deck containing the descriptor words was then sorted into alphabetical order and the n^{th} card of this deck received the serial number of

the n^{th} card of the numbered deck. This collated deck was then listed.

The above listing was used to add the see-also reference number which was then added to the punched cards by the key punch operators. Data for synonyms was then obtained and entered into a form for key punching cards. This latter deck was then listed and the listing proof-read. (Note: A synonym was distinguished by the letter S punched into the 75th column of the card.) This completed the processing of the deck of punched cards to be used for input data for the computer program for the generation of the dictionary wiring aid.

C. Programs for Production of Detailed Wiring Information

(1) General

This section presents information regarding the functions of the various programs, and the format of their associated punched cards.

The programs were run on the CDC-160A computer but were written to allow running on the CDC-160 computer. The data input and output medium is punched cards; however, the format of the input data is significantly different from the output data. The input data is in standard Hollerith code, but the output data is in a code of our own choosing since the computer can punch row-binary , i.e., any of the 960 possible positions on the card may be punched. Magnetic tape is required as temporary storage of the dictionary words and their associated serial numbers.

There are three relatively independent programs which, when taken together, will generate punched cards that will be used to aid in the wiring of the core stacks. The function of each of these programs is briefly stated as follows:

a The dictionary words, their associated serial numbers, and their see-also reference serial numbers form the input data for the first program which places this data on magnetic tape. The major portion of the program is devoted to extensive checking of the input data and also the data after it has been written on the

magnetic tape. Any deviation from perfect (i.e., an error) results in a stopping of the program necessitating a restart after the error has been corrected.

b. The second program reads the data on the magnetic tape generated in a above, translates it, and punches the cards used to aid in wiring the dictionary MIRF, one card per dictionary word.

c The third program uses the data on the document cards (input data) and the magnetic tape from a above to generate the cards used to aid in wiring the document MIRF, one card per document.

Somewhat more detail of the functions performed by these programs is given below.

(2) Input Data Formats

The input data punched cards are in two sets: (1) the dictionary input data, and (2) the document input data. The format of the dictionary input cards is shown in Table III-A and any columns of the card not explicitly listed are blank. The document input data requires two cards per document with the format given in Table III-B. Any columns of the card not explicitly listed are blank.

The majority of the dictionary cards were obtained by machine processing of the document cards.

(3) Program Functions*

a Tape writing program

1. The contents of one dictionary word card are read, the format of which is specified by Table III-A.

2. The input data is scanned and checked to see that the format of the data is correct and that only allowable characters are used, e.g., no numeric information in the field reserved for the dictionary word. Any error found causes termination of the program.

* The programs perform these functions but not necessarily in the order given.

TABLE III-A

FORMAT FOR DICTIONARY DATA PUNCHED CARDS

Columns	Data
3 - 12	Word (alphabetic characters, hyphen, or blank)
19 - 22	Serial number of word, octal notation for 12 bit binary number
25 - 28	Serial number of See-also reference, octal notation for 12 bit binary number
75	"S" if the word is a synonym, blank otherwise
77 - 80	Card sequence number (not used in computer)

TABLE III-B

FORMAT FOR DOCUMENT DATA PUNCHED CARDS

Columns	Data
3 - 6	Accession number: 4 decimal digits
8	Card number: 1 (2)[1]
11 - 20	Word number 1 (5)[2]
21	Asterisk for word number 1 (5)[3]
22	Link for words 1 (5) and 2 (6)[4]
25 - 34	Word number 2 (6)
35	Asterisk for word number 2 (6)
36	Link for words 2 (6) and 3 (7)
39 - 48	Word number 3 (7)
49	Asterisk for word number 3 (7)
50	Link for words number 3 (7) and 4 (8)
53 - 62	Word number 4 (8)
63	Asterisk for words number 4 (8)
64	Link for words 4 and 5[5]

Notes: 1. There are two cards per document, the numbers in parenthesis refer to the second card of the pair.

2. Alphabetic character, hyphen, or blank, only.

3. Asterisk or blank only.

4. Blank or 1 only

5. Column 64 on the second card of the pair always has a blank.

Note: This checking is extensive and comprises a major portion of the program, however, this is justified since errors that are allowed to pass uncorrected will propagate through the system.

3 The data is written onto magnetic tape and an automatic check is made by the computer. If a error results during the check a program interrupt occurs. For purposes of this program, it is assumed that such an error cannot be corrected and the program terminates.

Note: It can be seen from 2 and 3 that any flaw whatsoever during the execution of the program causes its termination. This has been done to insure perfection in the resulting magnetic tape.

b Dictionary MIRF program

1 The magnetic tape generated in a above is read, one dictionary word (and its associated data) at a time.

2 This data is translated both in format and code as specified in Tables III-C, III-E, III-G, and III-H.

3 A dictionary wiring card is punched in the format specified by Table III-C.

c Document MIRF program

1 A pair of document data punched cards is read and checked for correct format, i.e, data associated with one document.

2 The magnetic tape generated in a above is scanned for the corresponding serial number (and see-also serial number) for each descriptor word.

3 Once the serial numbers for all words of a given document are found, the superimposed code for that document is computed.

Row	Col.
9	1
9	2
9	26
9	2
9	1
9 8	

Notes:

TABLE III-C

FORMAT OF RECORD FOR DICTIONARY MIRF WIRING PUNCHED CARD

Row	Col.	Data
9	1	Presence of See-also reference, one core.[1]
9	2 - 25	Word serial number, 12 bits, two cores per bit. See Tables VII and VIII for the bit code.
9	26 - 27	Single odd parity bit for the word serial number, two cores. See Tables VII and VIII for the bit code.
9	28 - 39	See-also reference serial number: 12 bits, one core per bit.[2]
9	40	Single odd parity bit for the see-also reference serial number, one core.
9 8	41 to 60	Dictionary word, 10 characters, 5 bits per character, 2 cores per bit. See Table V for the character code.[3]

Notes:

1. Punch (a binary 1) indicates absence of see-also reference.
2. If there is no see-also reference, the see-also reference serial number is to be all binary ones (including the parity bit.)
3. If there are less than 10 characters, say n, then character n + 1 must be a "blank" code (see Table V). Characters n + 2, ..., 10 should have the "special" code of Table V.

TABLE III-E

ALPHABETIC CODE FOR DESCRIPTOR

Character	Punching Code 1	2	3	4	5	6	7	8	9	10
A	1	0	0	1	0	1	0	1	0	1
B	1	0	0	1	1	0	0	1	1	0
C	1	0	0	1	1	0	0	1	0	1
D	1	0	0	1	0	1	1	0	1	0
E	1	0	0	1	0	1	1	0	0	1
F	1	0	0	1	1	0	1	0	1	0
G	1	0	0	1	1	0	1	0	0	1
H	1	0	1	0	0	1	1	0	0	1
I	1	0	1	0	0	1	1	0	1	0
J	0	1	0	1	0	1	0	1	0	1
K	0	1	0	1	1	0	0	1	1	0
L	0	1	0	1	1	0	0	1	0	1
M	0	1	0	1	0	1	1	0	1	0
N	0	1	0	1	0	1	1	0	0	1
O	0	1	0	1	1	0	1	0	1	0
P	0	1	0	1	1	0	1	0	0	1
Q	0	1	1	0	0	1	1	0	0	1
R	0	1	1	0	0	1	1	0	1	0
S	0	1	1	0	1	0	0	1	1	0
T	0	1	1	0	1	0	0	1	0	1
U	0	1	1	0	0	1	0	1	1	0
V	0	1	1	0	0	1	0	1	0	1
W	0	1	1	0	1	0	1	0	1	0
X	0	1	1	0	1	0	1	0	0	1
Y	1	0	1	0	0	1	0	1	0	1
Z	1	0	1	0	0	1	0	1	1	0
BLANK	1	0	1	0	1	0	1	0	1	0
- (HYPHEN)	0	1	0	1	0	1	0	1	1	0
SPECIAL	1	1	1	1	1	1	1	1	1	1

Note: The alphabetic code is a five bit, 2 core per bit code.

TABLE III-F

ACCESSION NUMBER DECIMAL DIGIT CODE

Digit	Punching Code 1	2	3	4	5	6	7	8
0	1	0	1	0	1	0	1	0
1	1	0	1	0	1	0	0	1
2	1	0	1	0	0	1	1	0
3	1	0	1	0	0	1	0	1
4	1	0	0	1	1	0	1	0
5	1	0	0	1	1	0	0	1
6	1	0	0	1	0	1	1	0
7	1	0	0	1	0	1	0	1
8	0	1	0	1	1	0	1	0
9	0	1	0	1	1	0	0	1

TABLE III-G

PRIMARY WORD SERIAL NUMBER BIT CODE

Bit	Punching Code 1	2
0	1	0
1	0	1

TABLE III-H

SYNONYM WORD SERIAL NUMBER BIT CODE

Bit	Punching Code 1	2
0	0	0
1	1	1

4. The format and code of segments of the input data, the serial numbers, and the superimposed code are translated as specified by Tables III-D, III-F, and III-G.

5. A document wiring card is punched in the format specified by Table III-D.

TABLE III-D

FORMAT OF RECORD FOR DOCUMENT MIRF WIRING PUNCHED CARD

Row	Column	Data
9	1	asterisk for word number 1[1]
9	2	linking bit for words 1 and 2[2]
9	3-14	serial number of word number 1 (SN-1)
9	15	odd parity bit for SN-1
9	16	asterisk for word number 2[3]
9	17	linking bit for words 2 and 3
9	18-29	SN-2
9	30	odd parity bit for SN-2
9	31	asterisk for word number 3
9	32	linking bit for words 3 and 4
9	33-44	SN-3
9	45	odd parity for SN-3
9	46	asterisk for word number 4
9	47	linking bit for words 4 and 5
9	48-59	SN-4
9	60	odd parity for SN-4
9	61	asterisk for word number 5
9	62	linking bit for words 5 and 6
9	63-74	SN-5
9	75	odd parity for SN-5
9	76	asterisk for word number 6
9	77	linking bit for words 6 and 7
9 8	78 to 9	SN-6

Notes: 1. A punch (a binary 1) indicates no asterisk

2. A punch indicates no link

3. If there are less than eight dictionary words, then after the last word do not punch the next asterisk and link and then punch every hole to (and including) row 8 column 40.

TABLE III-D (CONT'D.)

Row	Column	Data
8	10	odd parity for SN-6
8	11	asterisk for word number 7
8	12	linking bit for words 7 and 8
8	13-24	SN-7
8	25	odd parity for SN-7
8	26	asterisk for word number 8
8	27	unused linking bit,
8	28-39	SN-8
8	40	odd parity for SN-8
8	41-72	accession number, 4 decimal digits, 4 bits per digit, 2 cores per bit. See Table VI for code.
8	73-74	odd parity bit for accession number,2 cores.
7	1 to	search field. 80 bits, one core per bit
7	80	

Note: Columns 75 to 80 in row 8 are not used.

APPENDIX IV

PREPARATION OF THE WIRED ITEM TRAYS

A. Introduction

The 1,000 document indexes and the 1,000 dictionary words of the delivered experimental model require storage of more than one-third of a million bits of information. The document index and dictionary word information is stored in permanent patterns of wiring associated with arrays of magnetic cores. The actual wiring patterns are implemented in modular form, as can be seen by reference to Fig. 29. This photograph shows an item tray that contains the detailed wiring for 286 words of the dictionary. In order to insure the greatest possible accuracy of the wired in information, two steps were taken. First, the raw data for the documents were computer-processed to give a set of punched cards that contain the detailed wiring information (see Appendix III). Second, a wiring scheme was devised which presented the detailed wiring information in a very simple form and which included a means of checking the accuracy of the wiring as the wiring was actually done. In this scheme, the path that a wire was to take was delineated by a set of lights in an array of incandescent lamps.

B. Description of Wiring Aid

An over-all view of the item tray wiring equipment (wiring aid) is shown in Fig. IV-1. The empty wiring tray is placed on the wiring jig in front of the operator. Number 36 Nyleze wire is taken from a spool through a tensioning device to the top of a special wiring tool (shown in the hand of the operator). The wire from the bottom of the wiring tool is first soldered to the common bus shown in the upper left part of the wiring tray. The tool is then moved along the path specified by the pattern of lights, leaving the wire wound in the desired pattern around the item tray bobbins. At the left center of the photograph, the punched card reader can be seen. This Taurus Corporation card reader tests all positions on one input card at a time (140 positions for a dictionary card and 2[illegible]4 positions for a document index card). A closed contact results for every hole in the punched

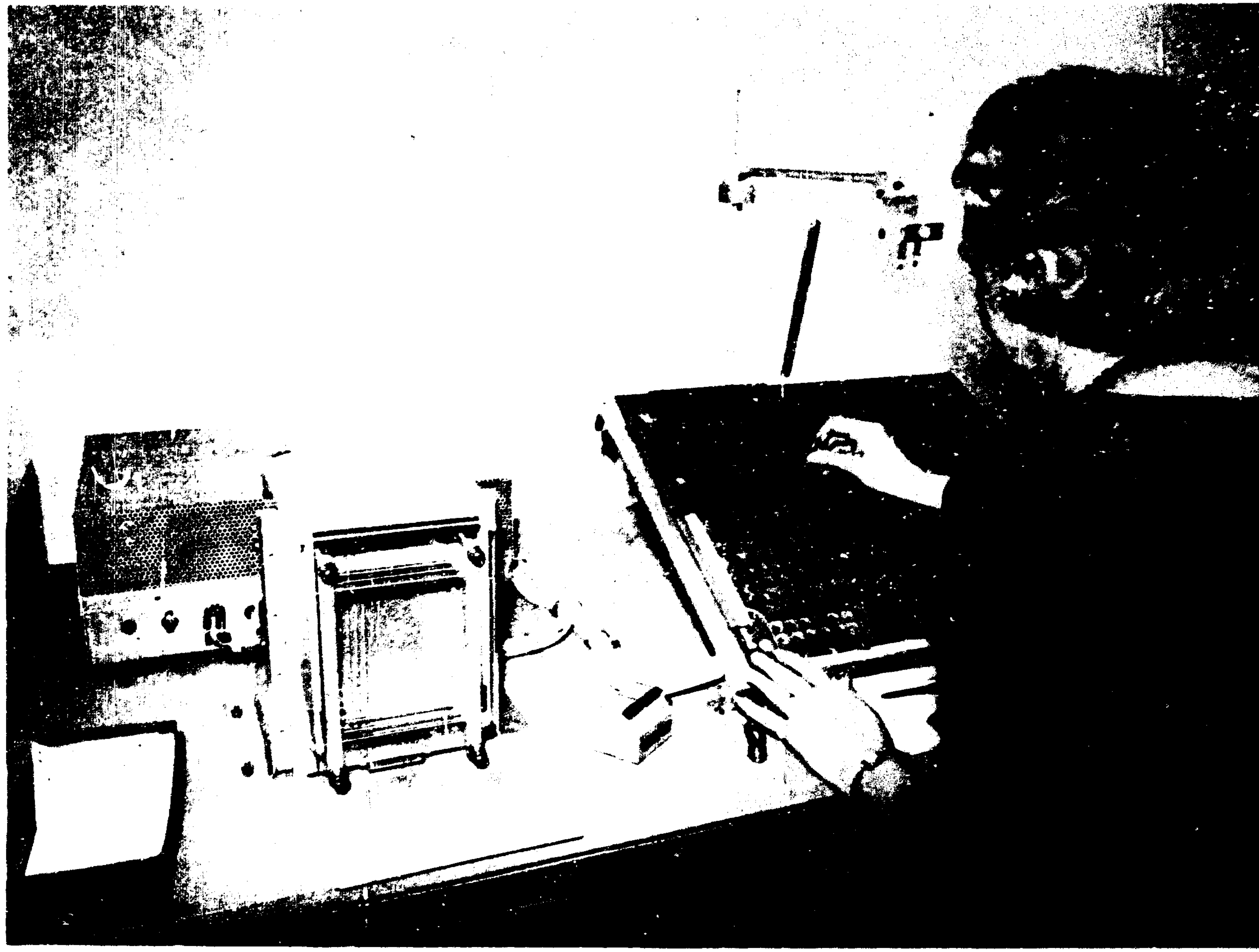


Figure IV-1. Over-all View of Item Tray Wiring Aid

card and open contact results for the absence of a hole. Each closed contact of the card reader furnishes a unit of current to the corresponding lamp in the wiring aid. Auxiliary circuits that are used in connection with the incandescent lamps are contained in the chassis that is shown behind the card reader.

Figure IV-2 shows a close-up of a partially wired dictionary item tray mounted on the wiring jig. The wiring jig consists essentially of a heavy aluminum plate with an array of square pegs that match the set of bobbins on the item tray. The outside dimensions of the square steel pegs are slightly smaller than the inside dimensions of the bobbins, thus permitting the item tray to be mounted over the wiring jig. Pairs of the wiring jig pegs are associated with single magnetic cores. The top two rows of pegs are associated with one set of cores, the next two rows with a different set of cores, etc. It will be noted that the center of each square peg is hollow and contains a component. The upper peg of each pair contains a miniature toggle switch with the bat handle operating in the vertical dimension. The lower peg og the pair contains a small incandescent light bulb. Depending upon the setting of the toggle switch and the condition of the corresponding switch in the card reader, a light bulb will receive zero, one, or two units of current. Consequently, a light bulb may be off, on at medium (brilliance yellow), or full brilliance (white).

The procedure for using the wiring equipment was as follows. First, all the test toggle switches were put into their initial position (down). Then the card reader was closed with no card inserted so that all switches would be closed. The array of lights in the wiring jig was then checked to make sure that every one was on at medium brilliance. This check made sure that all switches of the card reader were operating properly and that no light bulb had burned out. The punched card of the item to be wired was then inserted into the card reader. A pattern of lights in the wiring jig consisting of some lights on at medium brilliance and

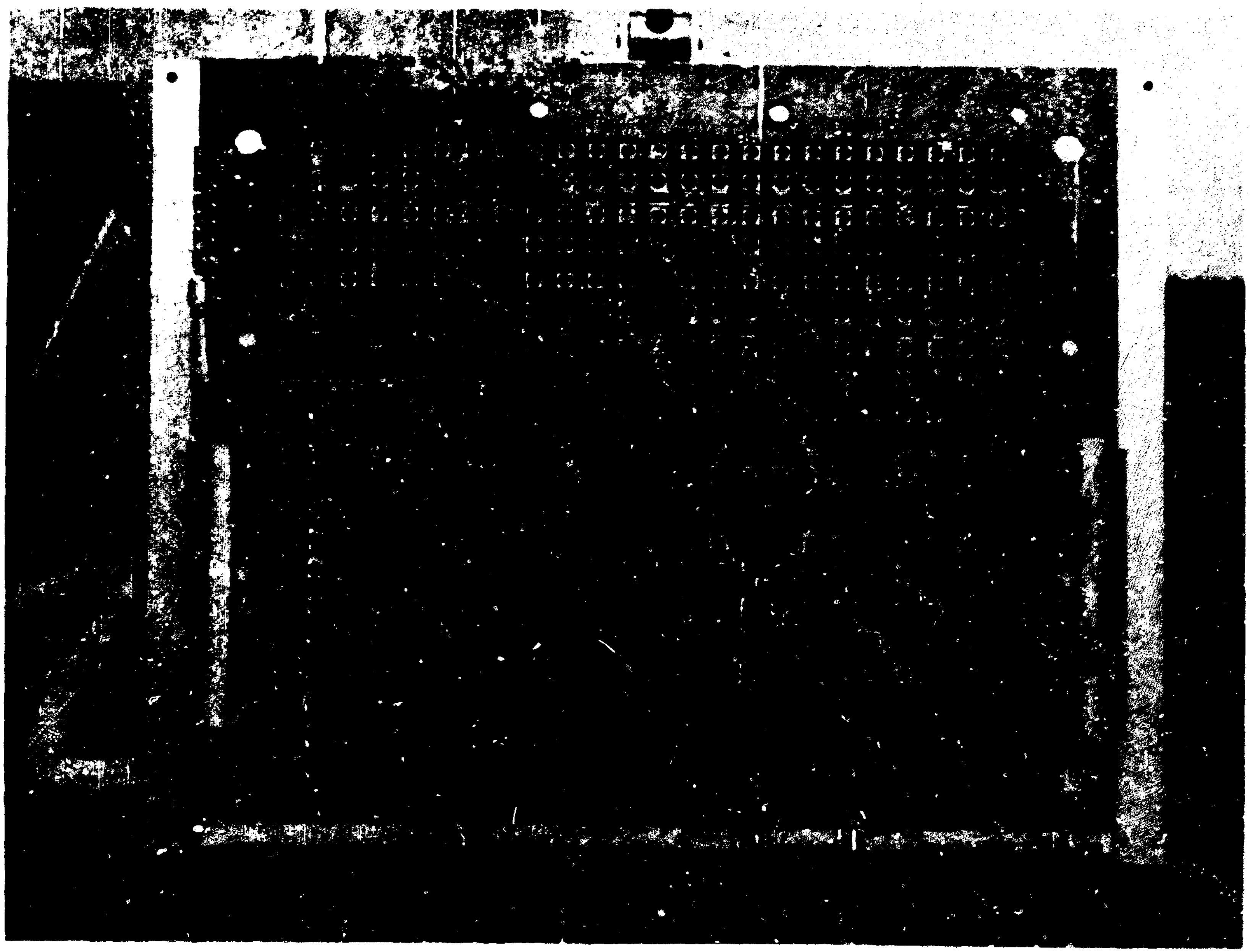


Figure IV-2. Close-up of Partially Wired Item Tray and Wiring Jig

some off was then obtained. The wire that was to be strung along the path outlined by the lights was first soldered to a terminal of the common bus. The wireman then started the special wiring tool at the upper left corner of the wiring jig and followed specific rules at each bobbin position. If the light was on, the tool was moved past the top of the peg that held the toggle switch. If the light was off, the tool was moved through the center of the pair of pegs and their associated bobbins. It was easy to move the wiring tool in such a path because the flanges of the paper bobbins formed a smooth surface on which the flange of the wiring tool could ride. Whenever the wiring tool passed through the center of a pair, the cam-shaped surface of the wiring tool flange caused the toggle switch to be thrown into the upper position. This caused the lamp to come on at medium brilliance. At the end of a perfect wiring operation, all lamps were on at the medium brilliance. Any error was easily detected. If a position had been threaded by mistake, the toggle switch would have been operated and an extra unit of current would make the lamp come on at white brilliance. If a position that should have been threaded was missed, the check toggle switch stayed in its initial condition and the lamp remained off. Both the lamp off and lamp at white brilliance could be easily distinguished from the medium brilliance of the lamp.

After all bobbin positions of a given row had been used, the wiring tool was passed around a pair of terminal posts and started through a row of bobbins in the reverse direction. Half of the items were wound on bobbins that corresponded to one leg of the array of cores, and the other half was wound on bobbins that corresponded to the other leg of the magnetic core. It can be seen in the photograph that all the wires that begin at the upper terminal board are wound around the row of bobbins nearest the top of the item tray. At the righthand end of this row, the wires pass over insulated posts and return right to left on the fourth row from the top. At the left end of the fourth row, the wires pass over two closely spaced insulated posts and go left to right on the fifth row of

of bobbins. The group of item wires that begin on the lefthand terminal board are wound on the bobbins in the second row from the top and return on the bobbins of the third row, etc. After a wire was wound on a complete set of bobbins, it was carried past bobbins used as binding posts to a sub-assembly of diodes. Here the wire was cut to length and soldered to one end of a diode.

C. Results of Using Wiring Aid

This wiring arrangement worked well in practice. The number of item wires that could be inserted per hour varied with the individual wireman, ranging from less than 40 to more than 60 for the document item tray which required wiring of 234 bobbins. The accuracy of the wiring was probably as good as can be expected when a human operator is involved. In the dictionary item trays, errors were made in less than 20 out of 1070 item wires. Most errors were single position errors, but a few were double position errors. If 25 total errors is taken as a round number, the error rate is one in 6,000 operations (there are 150,000 operations in wiring the dictionary trays). The accuracy of wiring the document item trays was somewhat better. One source of error was the operator's tendency to cheat on the check feature of the wiring equipment in order to speed-up the wiring process, by using her finger instead of the wiring tool to operate the check toggle switch.

APPENDIX V

ALTERNATE METHODS OF PREPARING WIRED-IN INFORMATION

The use of small wire wound on specially prepared bobbin trays is a satisfactory means of constructing the permanent store when the number of items is relatively small. However, it is recognized that this method would not be suitable if the number of items exceeded 5 or 10 thousand. During the development of the experimental Multiple Instantaneous Response File a small effort was directed toward investigating alternate methods of preparing the wired-in information. The object of this work was to select a method that could be used to prepare approximately 100 document index items and to make a comparison with the physical wire implementation.

Because of the very limited funds available for this effort, severe restrictions were placed on the fabrication techniques that could be investigated. The fundamental incompatibility of the aims and the means was that fabrication techniques that can be used in quantity production require large initial outlay of money that was not available. Because of this limitation one of the most attractive methods of preparing the wired-in information could not be investigated. This method* involves the controlled punching of holes in a continuous conductor "ladder" layed down on a thin insulating sheet to form a path that threads and bypasses core positions in the desired way (the initial cost of dies required for such a study would have cost more than 1/3 of the total funds allotted to this work).

The approach that offered the most promise of results within the ground rules of the investigation could be described as a printed circuit technique. A roll of copper coated mylar sheet (1/2 ounce copper on 2 mil mylar), obtained from the

*See RADC-TR-61-233, "Multiple Instantaneous Response File," by J. Goldberg et al, pp. 175-178

Schjeldahl Corporation, was cut up into pieces approximately the same size as the phenolic boards of the item trays. About 150 such sheets were piled up in a thick sandwich and held together under pressure by two heavy aluminum plates. The same drilling jig that was used in preparing the phenolic boards for the item trays was used, to drill a complete set of clearance holes in the stack of mylar sheets. This method was quite successful, giving blank sheets with a set of very clean clearance holes. Aligning holes for positioning the mylar sheets in a submodule comparable to an item tray were also drilled while the mylar sheet sandwich was still assembled.

The detailed wiring information was put on a copper coated mylar sheet by drawing a line on the copper with a pen and special ink. The wiring aid used with the physical wires was modified slightly for preparing the mylar sheet items. After the punched card of the particular item was placed in the card reader and the pattern of lights in the wiring jig was set up, the blank mylar sheet was placed on the wiring jig with the copper side up. Then a 50 mil wide line was drawn using the same instructions that were used with the wired item trays (wherever the control light was on, a horizontal line was drawn above the square peg, and wherever a light was off, a horizontal line was drawn in the center of the pair of pegs. Vertical lines connecting the horizontal segments were then added). The marked mylar sheet thus obtained was then passed through an etching bath, and all the copper except that needed to define the item conductor path was removed. A finished mylar item sheet is shown in Fig. V-1*. It will be noted in this photograph that the wiring conductor is connected to a bus at the top of the sheet and to another bus at the lower part of the sheet. These copper areas are used for connecting the item conductor to a common bus at one end and to a diode at the other. It will also be noted that a copper border has been left on the mylar sheet. This is for strictly mechanical purposes in order to keep a uniform thickness of the item sheet all around the edges. Seventy five such

*In this photograph, the top edge appears wavy because the mylar sheet was not flat against the backboard.

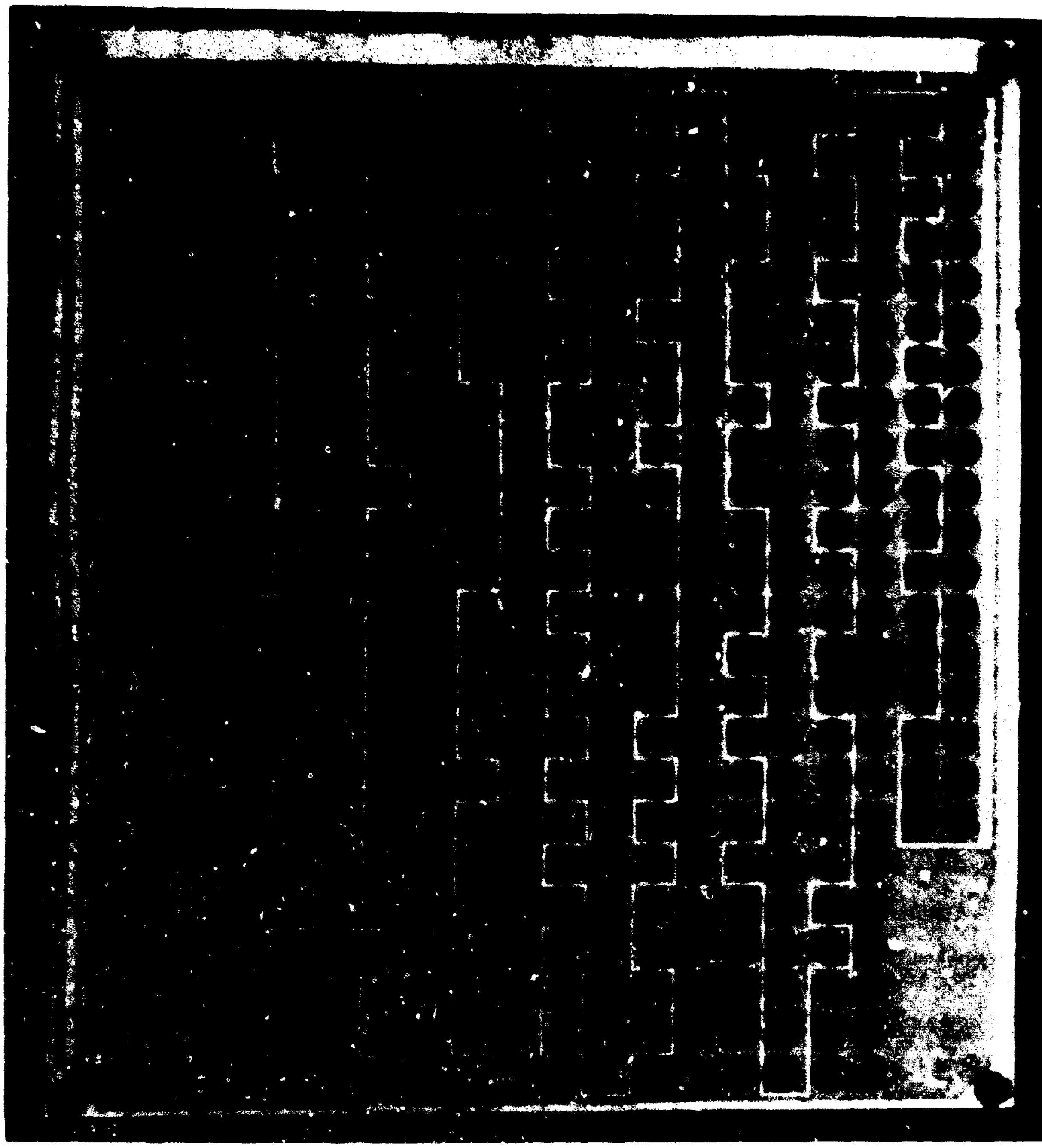


Figure V-1. Etched-Copper Mylar Item Sheet

sheets, each containing all the information of a real document index, were stacked and properly connected to the common bus and to output diodes to form a small mylar sheet submodule. This module is completely interchangeable with the wired trays and can be used in the document MIRF unit.

The preparation of the etched item sheets can be considered a limited success. Seventy five of about a hundred item sheets that were prepared in the wiring jig could be used in the mylar sheet submodule. About 25 percent of the sheets contained discontinuities in the conductor, ranging from width of a few mils to as much as about 30 mils. One difficulty appears to be the lack of control in the etching process. With copper as thin as 0.7 mil, overetching is a problem. Also, cleaning of the copper surface before the lines are inked requires special attention. Commercial degreasing techniques were tried unsuccessfully and the sheets finally used were cleaned by a weak pre-etch treatment. Handling of the cleaned sheets was also done with care. The operator worked with gloves and covered the copper surface with pounce. In spite of these precautions there is some evidence of the ink flaking away after it had dried. These difficulties are probably more a part of the experimertal approach than of the basic techniques. It is believed that proper controls could be held in quantity production and that a good yield of item sheets could be expected.

The item sheets that were prepared for the experimental model contained one item per sheet. This was done to simplify the preparation of these sheets. In practice, at least two item conductors could be placed on one mylar sheet, one being associated with one leg of the magnetic core and the other being associated with the other leg. By using a mylar sheet with copper on both sides of the mylar it would seem feasible to have as many as four items per mylar sheet. In this case an insulator would have to be placed between adjacent item sheets.